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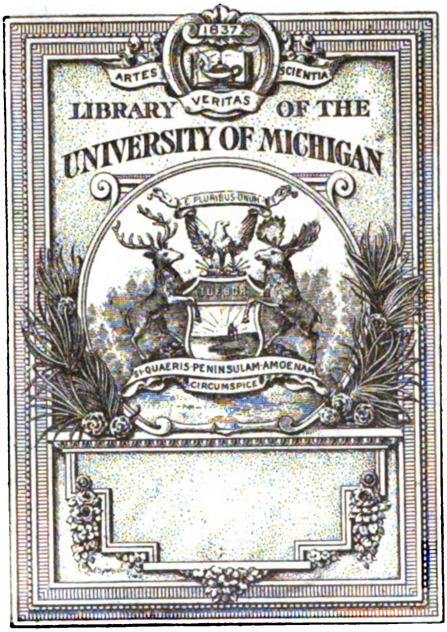

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Contents of Vol. I, No. 1.

I. The Correlations of the Volumes and Surfaces of Organisms. By John A. Ryder, Ph.D. (Plate I.) 3
II. The Growth of *Euglena viridis* When Constrained Principally to Two Dimensions of Space. By John A. Ryder, Ph.D. (Plate II.) 37
III. Descriptions of Three New Polychæta from the New Jersey Coast. By J. Percy Moore. (Plates III–IV.) 51

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I. The Correlations of the Volumes and Surfaces of Organisms.

By John A. Ryder, Ph.D.

1. It was long ago pointed out by Herbert Spencer, and before him by Leuckart, that, as organized unicellular bodies increase in bulk, their surfaces become proportionally less; and that this elementary rule of growth very probably leads to the necessity for segmentation or sub-division of the original cellular body, owing to the unfavorable conditions which continuous growth establishes between the organism and its surroundings, because of the more rapid increase of volume than of surface, thus developing unfavorable conditions for nutrition, respiration, and consequently, for metabolism and growth in general. It was assumed that the dimensions of the cellular body are in some way self-regulated, and that segmentation or cell-division is a method automatically resorted to during the growth of multicellular organisms, by means of which they are enabled to continually recur to more favorable conditions in respect to the ratios between the volumes and surfaces of their constituent cells.

2. The law of change of the ratios between volumes and surfaces of cells can be most clearly illustrated by two parallel series of numbers, showing the simultaneous increase of volumes and surfaces of a series of cubes whose sides increase at an integral rate, or by a difference of one; that is, a series of cubes whose edges measure 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, etc., taken consecutively. The first of the two parallel series may represent the surfaces of such a series of cubes, and is as follows: 6, 24, 54, 96, 150, 216, 294, 384, 486, 600. The second of the two series represents the volumes of the consecutive series of cubes and is simply the cubes of the first ten natural

numbers: 1, 8, 27, 64, 125, 216, 343, 512, 729, 1000. It will be seen that the first of these series, or the surfaces, vary as the squares of the sides of the consecutive cubes, multiplied by six, the number of sides of a cube. The volumes vary as the cubes of the consecutive numbers.

3. There are certain relations, however, of these three series of numbers that can only be clearly apprehended by placing them in superposed columns in order to indicate certain coincidences of equality and inequality at certain corresponding points in the series. This we may now do, thus:

Edges of cubes,	1	2	3	4	5	6	7	8	9	10	. .
Surfaces of cubes,	6	24	54	96	150	216	294	384	486	600	. .
Volumes of cubes,	1	8	27	64	125	216	343	512	729	1000	. .
These ratios of volume and surface may also be expressed thus:	1:6,	1:3,	1:2,	1:15,	1:1.2,	1:1,	1.16:1,	1.33:1,	1.5:1,	1.66:1	. .

It will be noted that when the volume is one the surface is six; that this great excess of surface gradually diminishes until the cube, with a side of six, has its volume and surface equal. Beyond this point it will be seen that volume outruns surface in a geometrical ratio. The equality of volume and surface at the dimension of six is noteworthy. Our first series is an arithmetical one, with a common difference of one. The second series is a geometrical one, increasing as the squares of the first series of consecutive numbers multiplied by six. The third is a geometrical one, and increases as the cubes of the consecutive numbers of the first series.

4. This same law applies to the relations between the volumes and surfaces of a series of spheres with their diameters increasing consecutively by a common integral difference.

5. The disadvantages to growth and metabolism which would follow according to this law of the relations between the volumes and surfaces, as the former increase, ultimately become apparent in growing, solid, unicellular bodies of any configuration whatever. This has long been known and the significance of cell-division, or the consecutive sub-division of the plasma of organized bodies into masses of certain dimen-

sions, as such bodies increase in bulk as growth proceeds, has been recognized, as before stated, as an automatic response to the requirements of metabolism as imposed by this law.

6. Growth, as expressed in a rearrangement, further subdivision of and addition to its material basis, has found, through the regulated *motion* and redistribution of that basis itself in space, several other ways in addition to segmentation, by means of which the consequences of the operation of the above law have been escaped. It is the purpose of this paper to follow up these further means of escape from the untoward conditions that led also to the operation of the famous Leuckart-Spencer principle above explained, and to show that these supplementary, but equally important principles are correlated with the *geometrical ratios* with which the forces of *growth, reproduction* and *metabolism* are simultaneously operative during the development, growth and the evolution of organic types. It may, indeed, be said that without resort to another type or set of equally important adjustments, which living beings have effected in relation to the outer world, the present development of organized existence, and even animal motion and mentality, would in all probability have been an impossibility. These new adjustments have made the possibilities of variation indefinitely great and various in every conceivable direction, since they have varied the fundamental forms through which variation was first manifested in the organic world.[1]

7. The primary form in which we find aggregations of organized living matter, is one that approximates the figure of the sphere. The shapes of such types as the *Micrococci*, the ova of many forms, the encysted stages of *Amœboids*, the living *Heliozoa*, many *Radiolaria*, some *Foraminifera* and some green, unicellular *Algæ* and some of their stages of encystment, as well as the encysted or spore stages of *Mycetozoa*, etc., exemplify this statement.

8. Since forms of this kind are nearly or quite of the same specific gravity as the water in which almost all of

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[1] It has been stated above that reproduction went on in a geometrical ratio during growth. By this is meant the geometrical ratio at which cell-division and consequent cell-multiplication proceeds during growth.

them are found, they are nearly or quite freed, as wholes, from the deforming influence of gravitation, so that their figure of equilibrium is that of a sphere, in which the infinitesimal attraction of every part for every other part of the sphere varies inversely as the square of the distance apart of such parts. Besides this, the far more potent inter-molecular attractions of the surface layer of molecules for each other, at insensible distances apart, is such, under the spherical condition, that it is everywhere equal at the surface. Consequently, the surface-pressures and tensions thus developed by surface-tension coöperate with the gravitation of the constituent particles in maintaining the spherical figure, or that in which every one of the infinite number of the radii of the spherical body is of nearly the same length as every other. The components of all the surface-tensions of a spherical organism are resolved at its geometrical centre.

9. It is, however, a very singular fact that this very primitive spherical form of body is one which is itself unfavorable for growth, with a proportionate and concomitant acquisition of new surface, since, of all forms of bodies it is the very one which can contain the greatest amount of matter within the least amount of surface. Therefore, any departure from the primitive spherical form of the body will increase the proportional amount of enveloping surface in respect to the volume of enveloped matter.

10. Now, we may do two things to the primitive spherical form with which we started, and two only, because, as will be shown later, dichotomy, or the splitting into bars, and lamination, or the splitting into slices, of a mass of matter amounts to the same thing as indefinitely extending it in the form of a cylinder, or spreading it in the form of a disk, without change of volume.

11. The two things that we can do to the primitive spherical form of a mass of living matter, are, more definitely, these: *First*, to extend it indefinitely in the form of a cylinder, with rounded or hemispherical ends, which becomes more and more attenuated as its length is increased; or, *secondly*, to press such a mass flat into the form of a disk with rounded

edges, and to maintain such pressure so as to indefinitely extend the expanse of both the faces of the resulting disk. In doing either of these things to the primitive spherical form we at once begin to increase one set of the surfaces of the resulting form of body in a geometrical ratio, and simultaneously begin to decrease another set in another geometrical ratio.

12. This singular result can best be illustrated as follows: Take a bar one inch square and 1,000,000 inches long, the area of its four long sides will be 4,000,000 square inches, and of its two ends only two inches. Now, let us shorten or compress this bar into a flat and square plate 1000 inches wide on a side instead of one inch as before, while its height or length has been reduced to one inch instead of 1,000,000 inches as before. The area of the sides now falls from 4,000,000 square inches, as in the case of the bar, to only 4000 square inches, while the area of the ends has increased from two to 2,000,000 square inches.

13. If we proceed to lengthen such a bar so that at each step it will be just half as wide across one of its four faces as it was at the preceding step, we shall have to quarter it lengthwise and put the four pieces so obtained end to end, so that we must make it just four times as long at every such step as it was at the preceding step. If we shorten it at the same rate, we must make it one-fourth as long as it was at the preceding step, but only twice as wide, since we need to take three of the four segments into which we have divided the preceding state of the bar to place against two of the sides and one corner of the fourth and last equal segment, in order to keep our rapidly shortening column square. A very little thought will enable any one to understand that thus lengthening and shortening such a bar so as to convert it into a very long square rod, or conversely transform it into a thin square plate, are two processes that are exactly the converse of each other. But it must be remembered here that the bar has neither lost nor gained substance during this process, that is, its volume has remained unaltered during these changes of figure.

14. Following the steps of our reasoning still further, if we extract the cube root of our 1,000,000 cubic inches we will get a cube of 100 linear inches on a side with a superficial surface of 60,000 square inches, which is the least surface which can be made to envelop 1,000,000 cubic inches and maintain a cubical figure, though a still smaller area could be made to cover our million cubic inches if we could squeeze them into a perfect sphere and thus develop a perfectly spherical containing surface. That is, the spherical enveloping surface is the one of *minimum* area which will cover or bound a given volume.

15. If we now take our cube with a volume of 1,000,000 cubic inches, since each of its six faces contains 10,000 square inches, we may take four of these for the sides and two of them for the ends of the column or disk, into which we shall alternately stretch and compress the whole mass represented by our cube. Starting, then, with the surfaces of the four sides and two ends of our cube, we shall have 40,000 square inches on its sides, while there are only 20,000 square inches on the two ends. We may place these two numbers in the centre of our table below, and if we multiply and divide, with appropriate numbers, in opposite directions, and with 40,000 and 20,000 as starting points, we will get a parallel series of numbers in two columns which will represent the correlative changes of the total areas of the ends and sides of our cube as we stretch its substance into a long, square column or compress it into a flat, square plate. To get the successive values of the areas of the ends produced by the shortening and compressing process, when, at each step the column is one-fourth as high as it was before, we must successively multiply or divide by four. To get the successive values of the areas of the two ends of the column when it is lengthened so as to be four times as long at every step as it was before, we must successively multiply or divide by two. We then find that as the sides of the column are indefinitely increased in length, they are increased in area, while the area of the ends approaches zero. Conversely, if the column is indefinitely shortened or compressed as supposed above, the

ends increase in area and the area of the sides approaches zero.

16. The two geometrical series thus obtained are convergent in opposite directions. They are also convergent in both directions, since, in virtue of the molecular constitution of matter, there must come a time when the molecular limit of tenuity of the attenuated column or square shall have been reached. In nature the similar series actually realized in organized bodies are all ultimately convergent, and could, if all the steps of their development were known, be summed.

17. The geometrical ratio of the series representing the expansion of the ends of the column as it is compressed is four, while the geometrical ratio representing the increase of the area of the sides as the mass is stretched is two, if the rate of stretching and compression proceeds according to the rule laid down in the preceding paragraphs. The table given below shows the two series increasing in opposite directions with the sums of the pair of terminal *b* and the four lateral areas *a* of the cube of 1,000,000 in the centre marked *C*. The series *a* converges at half the rate that *b* does, since the geometrical ratio of the progression of *a* is only half that of *b*.

The extremes 1.2+ and 327,680,000 of superficial inches of series *a* and *b* show the enormous difference between the areas of the ends and sides that is possible to develop by mere stretching or flattening of a mass of one million units of volume. The series *a*, for example, by no means exhausts the possibilities of development of area by means of stretching the mass. It would be possible, for example, to stretch such a mass of one million units of volume so as to extend it as a very slender straight bar for a distance several times the diameter of the earth's orbit without reaching the limit of breakage, due to having attained the size and coherency of the molecules in the mass by means of such continued stretching. Indefinitely developed series of surfaces of vast extent are produced in the annually recurrent formation of the leaves and terminal roots of very aged trees.

a

Negatively increasing series representing the successive values of the area of the sides in square inches as the cube of 1,000,000 cubic inches is lengthened by successive steps of four times the preceding length without change of volume.[1]

b

Positively increasing series representing successive values of areas of the ends in square inches of the cube of 1,000,000 cubic inches as it is shortened by successive steps that are one-fourth the length of the preceding without change of volume.

327,680,000		
163,840,000		
81,920,000		
40,960,000		
20,480,000		
10,240,000		
5,120,000		1.2 +
2,560,000		4.8 +
1,280,000		19.5 +
640,000		78.0 +
320,000		312.5
160,000		1,250
80,000		5,000
C 40,000	o	C 20,000
20,000		80,000
10,000		320,000
5,000		1,280,000
2,500		5,120,000
1,250		20,480,000
625		81,920,000
312.5		327,680,000
156.2 +		
78.1 +		
39.0 +		
19.5 +		
9.7 +		
4.8 +		
2.4 +		
1.2 +		

18. The seventh number, 5,120,000, of column *a*, is the sum of the areas of the four sides of a very long bar over 1,000,000 inches long, but with a very small area at the ends, as is

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[1] These two series are negative and positive, since they increase in opposite directions.

shown by the first number in the opposite column, or 1.2 +. The last number, 327,680,000, in column *b*, is the sum of the areas of the two ends of the very much compressed column still of the same volume, but now really a flattened, square plate with a side 12,800 inches long, while the height of the column, or the thickness of the plate, must be very small, as is shown by the area of the four sides, 312.5 square inches, shown in the column *a* opposite.

19. These results clearly establish the principle that, if one indefinitely stretches or flattens a cubical or spherical mass, the area of its surface will be augmented in a very rapidly increasing geometrical ratio, but that the ratio, at which surface is increased by flattening, is much greater than by means of linear stretching of the mass into a cylindrical filament.

20. An infinite variety of such series will be found to be actually realized in nature, but this one illustrates the facts sufficiently well for our purpose. The application of these results in biology will very soon be obvious to the reader. In fact it will soon be evident that in *two* ways, and in two only, have the ill effects of an adherence by Nature to the Leuckart-Spencer principle been obviated.

21. The volume of the body of a mammal, for example, grows in a geometrical ratio, or everywhere as the cubes of its increasing dimensions. The mechanism by which nourishment is prepared and conveyed to that mass, must itself be capable of developing surface in a geometrical ratio, else the entire body of the organism could not develop in the same ratio. We find, as a matter of fact, that in every detail of that mechanism its laws of development or growth are those of increased efficiency, according to the ratio of a geometrical progression.

22. This is effected by the stretching of parts by which their efficient surfaces are increased in geometrical ratios. The surface developed by the calibre and length of the alimentary canal increases at such a ratio. The area of the surfaces of the pabulum-bearing vessels is kept increasing in a geometrical ratio by dichotomy of the vessels

themselves. This dichotomy is, however, in reality, only a stretching process in disguise. The same takes place in glands; their tubules multiply by dichotomy, that is, essentially by extending or stretching their glandular surfaces, or in a geometrical ratio. So, too, the budding and distending or stretching of the alveoli of the lungs increase their aerating capacity *pari passu* with the growth in volume of other organs in a geometrical ratio. In the same way the efficiency of branchiæ is increased by dichotomy. We may in a similar way contemplate the ramification of the limbs of trees and the flat extensions of their tissues as leaves and the infinitely fine branchings of their roots; all of these organs thus develop correlative efficiency in a geometrical ratio.

23. Growth proceeds everywhere by adding to its substance at a rate which corresponds exactly with the rate at which the cube of the dimensions of the growing body is everywhere being increased. Since this last goes on in a geometrical ratio all the organs engaged in this business of growth must be continuously efficient and develop at a corresponding ratio. We find, indeed, that indefinite stretching or flattening of a mass would achieve the same thing as splitting it up into a great many slender bars, and placing these end to end, or, as splitting up the mass into a great many thin slices, and joining these edge to edge. In both cases a great gain of surface is accomplished. Now, if a body branches rapidly, it does the same thing as is done when it is split up into a great many slender bars, namely, it increases its surface in a ratio corresponding exactly to the rate at which the splitting or branching takes place. This is just what the vascular system has done in order that during growth its power of ministering to and maintaining the metabolism of the body could keep pace, not only with the geometrical ratio at which increase of volume was going on through growth, but also with the geometrical ratio at which metabolism itself was thus being established. The dichotomy of the vascular system, with its innumerable ramifications, is nothing more than a physiological response,

developed in a geometrical ratio, to a correspondingly rapid increase in the volume of the organized matter to be metabolized. The same principle is seen exemplified in the method of ramification of the roots of trees and the geometrical ratio of development of foliar organs, by which means alone both can be correlatively or reciprocally and continuously efficient. These reciprocally correlated geometrical ratios of development of the devices by means of which the processes of life in animals and plants are carried on have great significance in respect to the geometrical ratio at which the sexual and asexual reproduction of organisms goes on, and to the geometrical space relations of organisms, as contemplated in another essay.[1] It is clear, for example, that if every terminal axis of a plant may develop one or more perfect floral organs, that the production of seeds, if all the flowers are fertile, must proceed in a geometrical ratio, since the production of fertile axes proceeds in the ratio of such a progression. The importance of these arguments in relation to the mode in which a struggle for existence has been initiated must be apparent.

24. These principles may be extended in other directions. If, for example, the parts of an excretory gland are developed in a geometrical ratio by dichotomy, its function will be developed in the same ratio. If, moreover, the development of any organized surface in a geometrical ratio, or in some corresponding proportion, as surface and volume are related to each other, as determined by extreme stretching, flattening or dichotomy, then will the corresponding function or irritability of the part be developed according to the degree of stretching, attenuation or dichotomy of the part.

25. As an exemplification of the development of an enormous extent of metabolizable surface at the expense of a relatively very small mass of organized matter, the nervous system, of all organisms, is, perhaps, the most remarkable. Wherever developed it presents the same fundamental characteristics,

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[1] A geometrical representation of the relative intensity of the conflict between organisms.—Am. Naturalist, November, 1892, pp. 923–929.

namely, large ganglion cells, with partially insulated[1] motor or sensory *terminal* fibres, or fibres of *interrelation* of such extreme tenuity that their calibre is often to be paralleled only by cilia, flagella, or other highly irritable organs of cells. The extreme attenuation of the *terminal* and central *interrelative* fibres given off by the ganglion cells of the nervous system means a gain of surface in proportion to mass which is nowhere else paralleled by any active constituent tissue of animal bodies. Is this accidental, or is it that this enormous development of irritable surface is correlated with the extreme irritability of the nervous system, wherever such a structure is found? It seems fair to assume that the last part of the preceding sentence hits the truth.

26. This is exemplified by the tenuity of the nerve terminals of the auditory organs, as revealed by the beautiful researches of Dr. H. Ayers;[2] also in the olfactory, gustatory, tactile and sensory terminals generally of animals, and may even be remarked of the irritable structures of certain plants where hairs are points from whence irritability seems to be propagated, as in the irritable hairs of *Dionæa muscipula.* We also have fine illustrations of the same thing in the attenuated motor end-plates and plexuses passing to muscles as their terminal stimulating agents, or to terminal tactile structures.

27. In this connection it is to be remembered that it is also the most attenuated structures known to the histologist that are the most irritable, namely, cilia, flagella, etc. It is also just these structures which have the largest amount of surface, in proportion to their volumes exposed to incident influ-

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[1] The insulation of the course of the axis cylinders of the nervous system by a fatty envelope, the myelin sheath, suggests a parity with the recent discovery by Professor Elihu Thomson, that a sheath or envelope of oil forms an insulating material for metallic electrical conductors of extraordinarily high resistance. The axis cylinders of nerves are probably insulated by their fatty myelin sheaths. That nervous energy may be transmuted into electrical energy is sufficiently well established by what is known of the development of the electrical organs of fishes, in which, structures originally laid down as the rudiments of a muscular apparatus in the embryo, and consequently for the translation primarily of nervous impulses into an energy of motion through the muscular system, are transformed into a mechanism which transmutes those impulses into an electrical form of energy. The fatty myelin sheaths of nerves may also subserve an important nutritive function in relation to the axis cylinders.

[2] Journ. Morphol., 1892,

ences of oxidation and metabolism. As compared with the spherical or polyhedral forms of masses of protoplasm, usually characteristic of cells, very slender protoplasmic threads will obviously have an excessive amount of surface in proportion to their volumes.

28. The nervous systems of both vertebrates and invertebrates, with the extreme attenuation of the processes of the ganglion cells, as demonstrated in recent years, by means of the silver methods of Golgi and the methylene-blue method of Ehrlich, in the hands of Retzius, show how universally extreme tenuity of the processes of the ganglion cells is characteristic of a differentiated sensorium. It is not conceivable that this constant character of tenuity is accidental, any more than that the very common occurrence of rows or bands of cilia overlying the courses of nervous tracts in some lower types, or in larval forms, is accidental.

29. The irritability of a lymph-cell or an *Amœba*, with their blunt pseudopodia, is of a totally different character from the almost infinitesimally sharp-pointed protoplasmic rays of a *Helizoön*. In the extremely attenuated cone of protoplasm represented by a ray of *Actinophrys*, the conditions for respiration are infinitely better for a very small mass of protoplasm than in the massive pseudopod of an *Amœba*, in which the bulk of plasma in proportion to its enveloping surface is so much greater than in *Actinophrys*.

30. The correlations between volume and surface as expressive of the degree of irritability, as sought to be established above, yield us a view of the differentiation or origin of irritable protoplasmic structures proceeding from the bases of cilia and flagella, which would sink deeper into the organism as evolution progressed, so as eventually to lead to the differentiation of a specialized sensorium. The irritable, slender processes of the protozoan body, at first used for prehension and locomotion only, would locate the foundations of the nervous system; in fact, would map out, so to speak, the irritable regions and maintain their irritability by exercise of their functions. Such irritability would be reflected not only upon the protoplasm immediately sub-

jacent to the cilia in a protozoan, but upon the cells underlying and supporting the cilia in the primary stages of metazoan or multicellular development. Subsequently, the involution of the nervous system along what had earlier been ciliary bands would accomplish the inclusion and protection of the whole, and aid in a further differentiation of the sensorium. The outer cells supporting slender ciliary processes would eventually be thus involuted as ganglion cells, but their exterior ciliary terminations would still represent the peripheral sensory terminations, while the ganglion cell retained some motor and contractile powers in addition to its sensitive properties. As the motor powers of these primitive ganglion cells waned we can conceive them as extending themselves into contact with adjacent purely motor or muscular cells so as to become the mere transmitters to the latter of sensory impulses[1] which would be translated into motion by the contraction of the plasma of the motor cells thus brought about by impulsive contact stimulation.

31. The foregoing illustrations will serve to show how an adequate amount of surface is developed in a geometrical ratio by the stretching of plasma into threads, as cilia and flagella, by the stretching and branching of blood and lymph-vessels, of branchial filaments, of nerves, of the roots and branches of plants in order to maintain a physiological equilibrium and to escape the untoward conditions of nutrition and metabolism which would follow the retention of the spherical or any other homogeneous solid, massive figure of the cellular or entire animal or vegetable body.

32. Another mode of escape from the unfavorable condition imposed by the condition of a uniform spherical equilibrium is exemplified in the flattened, elliptical and circular forms of the red blood corpuscles. In these an increase of the metabolizing area of the plasma is achieved by mere flattening without too greatly complicating the form of the cell so as to unfit it for propulsion through the finest capillaries.

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[1] There is no evidence to show that the sensory and motor processes of nerves transmit impulses of a different nature, or that a sensory impulse differs in any essential respect from a motor one.

33. Another mode of escape from the bad physiological effects of the indefinite increase of a solid spherical mass is exemplified in *Volvox*, in which, as development proceeds, a larger and larger hollow sphere is formed, with the cells uniformly distributed over its surface, until a maximum hollow spherical dimension is reached. In this case, as the hollow sphere increases in size its surface increases as the square of its radius increases. This gives a geometrical ratio for the increase of the surface concerned in metabolism. Similar to this, in principle, is the growth of the blastula of many forms, and the growth of the blastoderm, amnion and allantois of many others. The vesicular gills of certain viviparous Cœcilians are another illustration of the same principle. The lungs and their development afford another, since we may conceive the lungs as an elastic hollow sphere, filled with a great number of very small hollow spheres with elastic walls, but all of them in communication with a common inlet and outlet, the trachea. We may further suppose that these hollow spheres are budded off from one another as persistent branches, and that as new hollow spheres are thus added, and as they grow in size, the metabolizing surface thus developed increases in a geometrical ratio, with the consequent growth of the entire lung, and *pari passu* with that of the body.

34. The development of flat branchial laminæ illustrates the principle of lamination or multiplication of surfaces by splitting into slices, compression or folding, while pectinate or fringed gills illustrate the multiplication of surfaces by stretching or dichotomy. The development of additional free surface in such a form as *Volvox*, in a geometrical ratio, commencing with a solid spherical stage, is achieved by a retreat of substance from the centre of the original spherical body to the surface, leaving the centre vacant. While there is really some acquisition of new material during this expansion of the hollow sphere in *Volvox*, if the wall of the hollow sphere or spherical shell of plasma were homogeneous, any dilatation of the shell would mean more or less stretching of its wall in every direction. This last case, therefore, becomes only a

special form of the compression and consequent extension in every direction of a flat membrane bounded by an inner and outer spherical surface.

35. The above rates of increase of surfaces of organs and tissues may vary within wide limits dependant upon the rate at which stretching or dichotomy of an organ is proceeding during growth, such as the vascular system, for example. In that case, if vascular branching occurs at equal intervals of length, at a uniform geometrical ratio, then will the geometrical ratio of the surfaces generated be uniform. If the branches given off at successive intervals multiply at different geometrical ratios, the surfaces generated will be formed at different rates of geometrical progression. Thus, if the branches given off at equal intervals are developed as to numbers in three different geometrical ratios, as follows, we may get the three following series representing the number of branches at six equal intervals apart:

1 . 2 . 4 . 8 . 16 . 32 . . . .
1 . 4 . 16 . 64 . 256 . 1024 . . . .
1 . 6 . 36 . 216 . 1296 . 7776 . . . .

The consequent development of surface will vary correspondingly. If the intervals between the members of the series, that is to say, if the branches were to vary in length, or if the series did not increase in a uniform geometrical ratio, the uniform increase of the geometrical progression would be disturbed. In this way it may, and probably does, happen that growth is disturbed in both plants and animals. If there were slight disturbances of the uniformity of development of any series, a new series would be developed. If increase were to take place according to the plan of the three series given, there would be a very great increase in the last form of the geometrical ratio at which the development of nutritive or metabolizing surfaces of any kind would take place. Such correlations and variations in the geometrical ratio of the development of roots and branches in plants must occur, so that an infinite multitude of such geometrical series must exist in nature, the last term of each of which must represent the statical equilibrium between one part of some given organism and all its other parts, as determined by the requirements of the existing conditions of its metabolism.

36. In plants of the higher orders the full-grown cells are usually vacuolated. As growth proceeds and the cells become older and larger, the central vacuole, filled with a watery fluid and surrounded by a thin mantle of protoplasm, is subjected to unequal osmotic pressures in different directions from within and unequal pressures from without, due to the unequal surface tensions and adhesions of the plasmatic cell-body and fusions and reciprocal resistances of the neighboring hard cellulose walls in different directions. Such unequal pressures cause a difference of dimension to be developed between the ends and lateral faces of such a hollow cylindrical or prismatic cellular body. The causes of the development of such differentials of pressure we are not called upon to discuss or explain here in detail, but only to note the fact of their existence, and to assume in crude outline, as is done above, the operation of known forces competent to produce the change of figure of the cell-bodies of plants, which begin their existence, as do cells in animal forms, as rounded or polyhedral masses of plasma. Roughly speaking, it may be added that, were the cells which enter into the composition of many of the tissues of the higher plants, related to the surroundings in exactly the same way, or as an equality in every direction, the figure would be a perfect sphere, such as is approximated by the figure of the body of *Volvox*. But such is not the case, since growth in plants reaches a maximum in the direction of one of the axes of the cells and a minimum in the two directions at right angles to the former, or in those which eventually become their two smaller dimensions. The flux of nutrient fluids through these cells is along the direction of the long axes; precisely what the mechanism is that effects this seems not to be clearly established by botanical authorities, so that all that can with propriety be said is that mechanico-physiological forces exerted unequally in three directions at right angles to each other, are the immediate efficient causes of the differ-

entiation lengthwise or along one axis of the primitively spherical vegetable cell. Growth so often reaches its maximum expression in one direction in the plant cell that it may be regarded as the expression of the general tendencies of the whole plant body, reflected upon the individual constituent cellular element, through the forces that are reciprocally active between the cells during the process of growth.

37. The point worth emphasizing in this connection is this, that in plants this stretching of the cell in one of its dimensions proceeds according to the table of ratios given in the earlier part of this paper, namely, that the surface of the lateral faces *increase* in a *geometrical ratio of two*, while the surfaces of the ends of the cells *diminish* in a uniform *geometrical ratio of four*, as lengthening or stretching proceeds, provided, the ends are at right angles to the long axis. If the ends are truncated at any angle these geometrical ratios do not hold in the same form, though the ratio of the lateral, as compared with that of the terminal areas of the cells, will still be very much greater. If the cell is greatly elongated it will be seen that the rate of flux of nutrient materials through its ends must increase or diminish according to the geometrical ratio at which its terminal surfaces increase or diminish. Now, this is just what does take place in plants. The development of the fibro-vascular bundles, and, consequently, the number of elongated cells, in plants, takes place in a geometrical ratio at each annual cycle of woody growth, since each annual cycle of such growth represents a larger circumference, so that this ratio becomes in turn a function of the squares of the radii of the entire stem produced by the successive annual accessions of growth.

38. We have already alluded to the geometrical ratio at which leaf-growth tends to extend the respiratory surfaces, supplemented as this is by the geometrical ratio, according to which leafy axes themselves are multiplied. It now only remains to point out that the flat epidermal cells will tend to extend the surfaces of their hollow bodies in a geometrical ratio of four, while the columnar palisade cells will tend to extend their surfaces in a geometrical ratio of two. Stomata

will tend to be multiplied in flat leaves in a geometrical ratio of four, while in linear or needle-like leaves, as in the conifers, they will obviously tend to multiply in a geometrical ratio of only two, as must follow from the law of development of the table given in the earlier part of this paper.

39. The development of a non-metabolic jelly, within a spherical colony of cells, as in *Volvox*, leads to the same thing in principle as the tension of fluids within the hollow cells of plants, by which the three dimensions of the cells are increased. There is this difference, however, the spherical surface increases as the squares of the successive values of the radius of the growing spherical body, while the geometrical series, represented by terminal and lateral surfaces of the prismatic plant cell, as the latter is stretched, is for the lateral faces an increasing, and for the terminal faces a decreasing one, provided the stretching, without change of volume, continues more or less indefinitely. If plant cells that are thus stretched lengthwise are chlorophyl-bearing, and at the same time superficial, they may offer the same respiratory advantages as the flattened or columnar respiratory cells of flat leaves, as in *Chara*, for example.

40. The development or secretion of a mass of jelly, largely of a non-metabolic character, as a supporting substance, as in *Volvox*, or as still more markedly shown in the jelly of the umbrella of *Medusæ*, may also lead to a geometrical rate of increase of surface, and thus develop a corresponding efficiency of respiratory surface *pari passu* with growth in volume. Such distension of an organism with a secreted product might affect its specific gravity, its statical equilibrium in the water of the ocean, the possibility of its survival, etc. It would also, in the case of the *Medusæ*, affect the elasticity of the rim of the umbrella, so that the radiating musculature on the under side of the umbrella needs no muscular antagonist, but would recoil when the radial muscles were relaxed, on account of the elasticity of the jelly itself.

41. *There may be very forcible reasons urged for the belief that the function of a cell reacts upon the figure of its own substance.* In such a case the figure will have its greatest exten-

sion in the direction of the exercise of its functions. *In other words, the physiological function of a cell is also a function of its figure, i. e., of its morphological character; that is to say, cells tend to elongate in the direction of the exercise of their functions.*

42. In proof of this, some of the facts given in the foregoing discussion seem ample. To make the evidence still more striking, a word must be said in regard to the mechanism of the motion of *Amœba*.[1] In this creature we have an organism in which the figure of the body is dependent upon its motion.

43. In *Amœba proteus* the surface-layer of molecules is continuously, or fitfully, ruptured at the end of the creature, which is for the time being anterior. This sets up a rush of new molecules from within, in the direction of the rent, to form a new surface-layer. Immediately that the new layer of molecules at the rent are in equilibrium in relation to inner and outer influences, or in a state of temporarily stable surface-tension, the latter is again disturbed at the same or an adjacent place. A new rupture of the surface-layer occurs, and a new outpour of fresh molecules from within takes place to establish a new equilibrium of surface-tension. This process goes on indefinitely in this manner. The result is that the organism is, so to speak, continually ripping itself open anteriorly, in order to let some of itself out of itself to repair the successive rents in the molecular skin of itself. In this way its substance flows along, not continuously, but more or less fitfully, the fitful motion being due to the manner in which the rents in the body are being continually repaired in rapid succession by a flux of new material from within.

44. But if this is true it must also follow that a central current of the protoplasm of the body of the *Amœba* is thus set up. This, as a matter of fact, happens. The central part of the current in the body of the organism flows fastest, while

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[1] The recent deliverances of Professor Greef, as to the existence of a musculature (!) in the "ectosarc," of some of these animals, is a physiological and mechanical impossibility, as will be seen from what has been given in my account of the facts.

as one proceeds toward the periphery, in either lateral direction, the current becomes slower and slower, until the surface layer is reached, which is seen to be quite immobile. The flow of materials in *Amœba*, therefore, obeys the laws of flow of fluids in a channel, such as water in a river, the current in the central part flowing fastest, while that next the bank flows slowest, until nearly absolute quiescence of the outermost film of molecules next the solid margin is attained. So in *Amœba* the central current is rapid, while the outermost layer of molecules, forming the body wall, are immobile, and form a tubular fixed shell through which the substance of the organism is flowing.

45. A further study of the creature convinces us that the body of *Amœba* is truly a smoke-ring-like body, or a *vortex-ring of particles*, distorted, it is true, by gravity, adhesion, unequal surface-tensions and the viscosity of its own substance, and the direction of its own motion, but a *vortex-ring* of particles it is, nevertheless. As a consequence, the living matter that forms the temporary tail-end is continually being transported to the head-end. In other words, the substance of the animal is flowing into itself behind and out of itself in front. In this way it is enabled to translate its body from place to place, and in this way only. In this way, too, it comes about that what was "tail" is continually becoming "head," and what was "head" is continually becoming "tail." A *Proteus*, truly, is this creature thus incessantly crawling into and out of itself. From this it is easy to see what must become of the muscular (?) fibres of Greef. They would be converted into oval or oblong rings. Such, however, are some of the will-o'-the-wisps that morphologists will follow to no purpose.

46. The number of directions in which such a living vortex-ring of particles may be made to move is infinite in number on a plane. It has no fixed head; no fixed tail-end; all is still chaos so far as its morphology is concerned. It exhibits phenomena which physiologists almost universally confound and wrongly indentify with muscular contractility. There is scarcely anything more than a remote analogy between what

happens in the motion of an *Amœba* and what happens in either a voluntary or an involuntary muscular fibre. In the *Amœba* the number of possible axes of flux of material is infinite, in muscle there is but one axis, constituting a difference which entails a totally different method of the distribution of the motions of the materials involved during motion or contraction in the two cases. In the muscle the vortex-rings are double, and there are probably as many of these double vortex-rings of particles developed during contraction as there are sarcoplasts and fibrils in a single voluntary fibre, while in *Amœbæ* there is but one vortex-ring of particles, with a rolling motion in one direction; in muscles the double vortices roll in two opposite directions, face to face.

47. Elongation and contraction, however, follow the same law of change of dimensions in both *Amœba* and muscle as are represented in the table of geometrical ratios given in the first part of this paper. As we may contemplate the shortening of *Amœba* and of muscle as either the contraction and dilatation of a single vortex-ring or of a great many *vortex-rings of particles* placed face to face, the fundamental curve traced by using the length from which the one set of the geometrical ratios of the table are calculated, as ordinates, and one-half the square root of half of each one of the other set as abscissæ, gives us not only the universal muscle curve, or curve of contraction of living matter in its most generalized form, but also a curve according to the law of the formation of which the lateral and terminal surfaces of all organized bodies change their geometrical ratios with respect to each other when such bodies or their parts are either indefinitely stretched or flattened in the form of a column elongating at a uniform rate, a disk widening at a uniform rate, a hollow prismatic or spherical mass of matter being distended or collapsed at a uniform rate.

48. It is singular, if not paradoxical, that the metabolizable superficial area of a muscular fibre diminishes in a geometrical ratio in the progress of its contraction, as the law of the formation of the curve of contraction shows. There are other anomalous cases of the development of this curve, one of the

most remarkable being that which occurs in the process of peristalsis in the intestine.

49. For our purpose the intestine may be regarded as a straight, hollow cylinder or tube, the contents of which are being renewed so frequently that they are not very far from constant for at least a considerable portion of the extent of the small intestine. If we make the assumption that the volume of the cylinder represented by the walls of the intestinal tube does not vary greatly from a constant one for a considerable part of its length, when *shortened* and *widened* by contraction of the outer longitudinal coat of the muscular fibres, or *lengthened* and *narrowed* by contraction of the inner circular coat of muscular fibres, we make the same geometrical assumptions as when we are dealing with a hollow cylinder with closed ends and filled with a labile or fluid mass. If an ideal or imaginary cylinder with closed ends have uniformly elastic and homogeneous walls and be perfectly filled with fluid, it can be made to change its cylindrical figure, or the ratio of its diameter in respect to its length, but not its volume. These changes of the two dimensions must obviously take place according to the same law as is followed in the contraction of a muscular fibre, and the angular intersection of the two dimensions of a hollow cylinder, at the junction of one of its ends and its mantle, as these change in length during shortening, would describe a curve identical with that described by the contraction of a muscular fibre. The effect of these conditions, supposing the fluid contents of the hollow cylinder, with its elastic walls, to be incompressible, but with the fluid particles displaceable in respect to each other, is that, when the elastic substance of the wall of the cylinder is stretched, any longitudinal segment or strip of its lateral face will be simultaneously compressed at right angles to the long axis of the cylinder, while any very small circular segment will be stretched or widened in the direction of the length of the cylinder. It also results from this assumption that every indefinitely small circular segment of the wall, cut off at right angles to the axis of the cylinder, will be found to measure less across the diameter of its circumference than before the

cylinder had been stretched. These changes in the ratios of the length of a lateral longitudinal strip to the circumference and diameter of a small circular or ring-like segment of the wall of the elastic cylinder will proceed according to the law of the development of the curve spoken of above. If we reverse the direction in which contraction takes place and cause the cylinder to shorten, it will then become greater in diameter. This process will stretch every indefinitely small circular segment into a wider and thinner ring of matter. From the same cause every linear strip or segment of the wall of the cylinder will be shortened and widened, so as to become a thicker strip of matter. If we now replace our conception of a cylinder, with homogeneous elastic walls, with one in which there is present an outer layer of longitudinal fibres and an inner layer of circular fibres, but with the ends closed with an elastic membrane, and the whole filled with fluid, we get the same result in another form. If we now stretch our cylinder with its fibrous walls, the outer fibres are individually stretched, become thinner or more attenuate and more closely packed together. The inner layer of fibres, on the contrary, are compressed, that is, they may contract into smaller circles and the individual fibres must become thicker through. If this process is reversed, that is, if the cylinder under the same conditions is shortened, the outer layer of longitudinal fibres must become individually shorter and thicker, while the cylindrical mantle or envelope which they form, as a whole, is thus increased in circumference but decreased in length; at the same time, the inner coat of the circular fibres relax or lengthen so as to form larger rings, and the bodies of the rings become thinner, and consequently more closely packed together.

50. Under these conditions, the two coats of fibres, if endued with contractility, become the *perfect* and *absolute antagonists* of each other, so that when the outer longitudinal coat of fibres contract they must shorten, swell and form a wider but shorter tube, while the fibres of the inner circular coat must relax and form longer and thinner rings, which are more closely crowded together. When the inner coat of cir-

cular fibres contract they form smaller rings, with the diameter of the individual fibres increased, while the longitudinal fibres are relaxed so as to become longer and more slender and more crowded together, and also as a whole system contracted to a narrower and longer tube.

51. These two coats of fibres, acting at right angles to each other everywhere in the wall of the intestine, are thus seen to be absolutely perfect and necessary antagonists of each other in virtue of the geometrical laws that we see must hold in respect to the change of figure of a cylinder having a constant volume, but in which the ratios of the diameter and length are changing. This remarkable antagonism is a fact in spite of the condition that the two sets of muscular coats cannot antagonize each other in the manner in which the extensors and flexors of the limbs of the vertebrate body operate, since they exert their forces one outside of the other instead of directly against each other over some *point d'appui*, or fulcrum, as do the latter. Not only is there this lack of direct linkage, as in the case of the flexors and extensors, but there is the further remarkable correlation of the processes of contraction and relaxation of the individual fibres by which room is provided for them, automatically and correlatively, as the figure of the cylinder changes, due to the simultaneous contraction and relaxation of the inner circular and outer longitudinal coats of fibres. The two coats cannot contract simultaneously in virtue of the geometrical conditions imposed from the start, viz., change of figure without change of volume of the imaginary cylinder, with perfectly elastic and homogeneous walls filled with an incompressible fluid formed of freely displaceable particles.

52. The remarkable fact of the perfect correlation and alternation of the changes of the dimensions of the individual fibres at right angles to each other and lying in two layers in two general directions at right angles to one another, is no less remarkably supplemented by the fact that, under the fundamental assumption in respect to the change of figure but not of volume, the curve traced by these hollow or tubular muscles as wholes, or when in combination as inner circular

and outer longitudinal tubular coats is exactly the same as that for a solid muscle, such as a flexor or extensor of the limbs, the equation for which has been very kindly worked out for me by my colleague, Dr. A. P. Brown. This curve and its mathematical formula is given in the appendix to this paper. The universality of the law expressed by that curve in respect to the ratios between volumes and surfaces is its most remarkable property. The law of contraction expressed by it is, however, also established even for the complex, hollow musculature of the intestinal wall, since the curve traced by a point placed at the angle formed by the junction of one end and the side of any cylinder or prism that decreases in length, while it increases in diameter without change in volume, is the same as the curve traced during the contraction of a muscular mass.

53. But one must here make an important proviso, which is almost paradoxical, yet perfectly true, namely, that under the law of *contraction* expressed by that curve, the *outer* coat of the intestine *contracts* while the *inner relaxes*, while under the law of *relaxation* expressed in the negative or opposite direction along the same curve, the *outer* coat *relaxes* while the *inner* one *contracts*. These relations are thus seen to be most exceptional. These singular contrasts and exceptions in the behavior of the muscular coats of the intestine as expressed in opposite directions along the curve referred to must, therefore, be indicated with opposite signs, or as — and +, as is done in algebra with quantities or in quaternions with respect to the direction of motion or energy-flow along a vector.

54. These very remarkable laws governing the actions of the muscular coats of the intestine apply also to the muscular coats of blood-vessels and other tubular structures, but do not apply to a case where the muscular fibres have a spiral course around a tubular or hollow organ. In the latter case the law of the muscular curve remains true, but all of the spiral fibres must relax and contract together or in company, and thus affect the calibre and also the length of the canal they surround, which would be impossible with the simultaneous con-

traction of the fibres of both of two coats at the same point running in two directions at right angles to each other.

55. There are certain applications of these facts and deductions which are of great importance phylogenetically; in fact, it was the study of the body-wall of *Vorticella* that led the writer to undertake to clear up the difficulties that beset one in reflecting upon peristalsis. The body of the bell-animalcule represents a figure of revolution, say approximately, a paraboloid. It changes from one where the base of the paraboloid is narrow to one in which it is much wider during contraction. According to the laws of contraction just established for hollow or tubular muscles, when the bodies of some of the species of *Vorticellidæ* contract or shorten, their surfaces are thrown into closely crowded circular folds, markings or wrinkles encircling the body. When they relax or extend themselves these circular markings or wrinkles tend to disappear, and, since the circumference of the body now diminishes, longitudinal and parallel wrinkles or markings tend to appear on the cuticle. These wrinkles are thus seen to cut each other across at right angles and thus to sculpture the walls of some of the species of these animalcules with the most regular quadrangular patterns. The ornamentation of the cuticle, or differentiation of the ectosarc of some of the *Protozoa*, is accordingly seen to be controlled by the geometrical law governing the order and direction of the contractions of the walls of a cylinder, a conical tube, or hollow paraboloid as above elaborated.

56. In the very simplest forms of intestine, as seen in the common Isopod *Oniscus*, the wood louse, or sow-bug, the circular and longitudinal fibres are cross-striate and form a mesh-work which looks under the microscope like a coarse wire-screen with open quadrangular meshes. In every mesh there rests a large square or rectangular epithelial cell with a large nucleus. Outside of the muscular coat comes a thin chitinous intima or cuticle, which is differentiated into quadrangular areas corresponding to the square meshes of the longitudinal and circular coats (here each composed of a single layer of fibres), and to the outer faces of the individual

epithelial cells. No one can contemplate this very beautiful mechanism in the light of what has just been said of *Vorticella* without being impressed with the conviction that the same law holds here in respect to the mode in which the quadrangular form of the epithelial cells was brought about in relation to the two sets of muscular fibres running at right angles and contracting according to the singularly exceptional and interesting rule laid down in respect to the methods of contraction in the intestinal wall of a mammal.

57. Our interest does not abate here, because we find that under the conditions just established for the cells of the intestinal epithelium, when the circular fibres contract, each one of these cells is squeezed into the form of a right parallelogram with the longest side parallel with the central axis of the intestinal canal. Should the longitudinal fibres contract, each epithelial cell will still be a right parallelogram in outline, but its longest side will now be parallel to a circumference of the intestine lying in a plane at right angles to its axis. This dynamical see-saw or alternate change in two of its dimensions of each epithelial cell of the intestinal wall of *Oniscus* is very remarkable and instructive, and must be one of the agents at work in keeping this epithelial layer active in the processes of metabolism, since every such cell is subjected to a sort of constant physiological massage, first upon two opposite edges, then upon the other two, at right angles to the first pair.

58. It may be stated further that the quadrangular form of the large epithelial cells could, mechanically considered, not long persist in any but the square form described, since if they did not at first they would ultimately be compelled to become rectangular in outline owing to the way in which the muscular forces alternately exhibit themselves at right angles to each other, upon two of the four faces of their plastic substance.

59. It is also probable that the peculiar arrangement of muscular coats of the intestine of vertebrates has tended most distinctly to throw the lining epithelium into longitudinal folds and ultimately into villi, or that the crude mechanical

action of the alternate contraction of the inner and outer coats would distinctly aid in developing a gain of surface, which must in the main take place according to the rules laid down in the earlier part of this paper, or partly in the guise of a physiological response to the requirements of a greater surface absorbent of nutriment. The inner circular coat would tend to produce the longitudinal folds, while the outer longitudinal coat would tend to bend and break these folds up into shorter ones and ultimately into villi. The phyletic history of the intestinal epithelium is distinctly in favor of the foregoing view, since the lowest vertebrates (*Marsipobranchs*) have only longitudinal folds of the epithelium developed. It can at any rate be reasonably supposed that the development of the folds and villi in the intestine of higher vertebrates was materially aided by the means suggested above. Other examples of longitudinal foldings produced by circular or tubular muscular coats are found in the longitudinally folded epithelium of the bronchi, and the longitudinal wrinkling of the fenestrated membrane in the contracted state of arteries. It is probable, therefore, that even the development of the villi of the walls of the intestine may be brought in a measure under the domination of the mechanical laws of the distribution of physiological energy, and, therefore, of *mechanical genesis*, as that expression has been used by Mr. Spencer and myself.

60. The mechanism of peristalsis remains to be considered, since it is inadequately treated in the latest authoritative treatises on human physiology. As defined by physiological writers, "*peristalsis is a progressive narrowing of the intestinal canal, which travels as a wave of contraction of the inner coat from above downward.*" This definition must be qualified and we must add the following: *Preceded or followed by a wave of contraction of the outer longitudinal layer of fibres, which has the effect of dilating the intestine at the point of contraction of the longitudinal fibres; such dilatation moves along with, before or after, but at the same rate as the wave of contraction of the inner coat.* This arrangement amounts to practically the same thing as to suppose the bulb of an

ordinary bulb-syringe, capable of traveling along the tube of which it forms a part. The peristaltic apparatus is to all intents and purposes a tubular pump similar in its action to a bulb-syringe, in which the bulb is translatable along the tube in the direction of the flow of fluid in the tube, while the constrictions before and behind the dilatation may be fairly compared with the valves of the bulb.

61. As stated at the outset the outer coat must be relaxed when the inner is contracting, while the inner must relax when the outer contracts. This implies nervous inhibition for the first of the two pairs, and stimulation for the last of the two pairs in the order given in the last sentence. In other words, inhibition is simultaneous with stimulation in each of the two possible orders of permutation of the actions of the two coats. Now, there is only one layer of ganglion cells with its plexus between the two coats innervating them; how that nervous plexus of Auerbach can alternately inhibit and stimulate the coat outside of itself, further research must evidently decide.

62. The very remarkable set of muscular forces developed as above set forth in peristalsis, must also react in a profound way upon the absorption of lymph and chyle, since peristalsis must be almost as active in progressively compressing the sub-mucous and intravillous lymph-passages downward as it is in shoving along the contents of the intestinal canal.

63. The whole of the foregoing discussion has centered about the development of a single formula or law, according to which the correlative changes proceed in the two groups of areas into which the surface of the cube or sphere with which we started is at once divided, if we either stretch or compress either of these two forms of bodies without altering their volumes. In either direction additional surface is developed in a ratio of geometrical progression. Organisms have proceeded to develop surfaces during their growth in volume according to this rule of geometrical progression, and have thus evaded the suicidal consequences of an adherence to the figure of simple spherical equilibrium or spherical shape, which we have reason to believe characterized organic bodies

or masses, nearly or quite freed from the disturbing influence of the earth's gravitation in the water in which they were suspended, as well as inorganic or cosmical masses in space, in obedience to the mutual and equal attraction of all their parts for each other. Organisms have evaded the disadvantages of an adherence to the spherical form or forms of natural gravitational and surface-tensional equilibrium through variable adaptive responses of their own living substance to their surroundings. How, in the case of unicellular organisms these departures in opposite directions were achieved, except through an internal mechanism of the protoplasm itself, is simply incomprehensible. This mechanism must be supposed to exist in and characterize the molecular structure of each form that has so varied from the primitive spherical type. This molecular difference saturates or characterizes every particle of an organism, nucleus, nucleolus and cytoplasm, otherwise the mechanism cannot be conceived to be complete. The uselessness of gemmules, plastidules, pangenes, germ-plasms, idioplasms, etc., as helps to a comprehension of the phenomena of heredity, must be obvious if we contemplate the facts in this way.

64. Three fundamental modes of response of living things to a change of environing conditions we have found, and only three. In three ways only did living Nature find it possible to escape the conditions imposed by the simple aggregating impulses of the forces of gravitation and surface-tension. All three of these expedients have been resorted to, with all their multiform consequences, by the *Protozoa* and *Protophyta*, so that it is now difficult to decide which was actually the most primitive form of the three, the segmenting spherical, the attenuate cylindrical, or the flattened discoidal. The multitude of intermediate forms and combinations of the three primitive morphological types, in endless variety, shows how resourceful the internal mechanism of protoplasm in relation to the outer world has been in striking balances, or affecting adjustments, the beauties of which can never weary the naturalist, even if he were not to go beyond unicellular animal and plant-forms.

65. The vacuolation and gradual dilatation of the simple, spherical form into a vesicle or segmented blastula probably led to the evolution of *Metazoa,* while indefinite lengthening and branching of cell aggregates seems to have been the line along which plant-cells became coherent in the course of the progressive evolution of the *Metaphyta*, or higher plants. The latter, in fact, present an ultimate vacuolation of every cell accompanied by a maximum stretching in the direction of elongation. This vacuolation might be regarded as a fourth fundamental form were it not that it is in reality only a very special form of flattening or compression, since the indefinite expansion of a homogeneous spherical shell means the same as indefinitely extending and attenuating a membrane of double spherical curvature.

66. The changes of shape suffered by all organisms during their evolution and departure from their primitive spherical forms therefore, may be reduced to two categories:

I. Indefinite stretching of some or all of their substance in linear directions of which dichotomy, or branching, is only a special form.

II. Indefinite flattening, compression or attenuation of some or all of their substance into a flat plate or into laminæ. The vacuolation of a mass of plasma, spherical or prismatic, so far as the laminar attenuation of the mass is concerned, falls properly within this category. The longitudinal extension of such a closed saccular mass as a hollow, but closed cylinder or prism, falls partly under the first category.

The application of these conclusions to any and all existing organic forms must be left to the reader.

APPENDIX.

The curve according to which the two fundamental changes occur, which are incident to the development of surfaces in organisms, is reproduced below as calculated for a constant volume, and had reference originally to the changes which take place during the contraction of a muscular fibre. The curve, has, however, been developed in the figure far beyond the possibilities of the contraction of muscle, so as to serve equally well for the illustration of the correlative changes in the geometrical ratios subsisting between the lateral and terminal surfaces of a mass of matter of constant volume as it passes from a condition of considerable elongation to one of extreme compression. The calculation is based upon a volume of 100 cubic units. As the volume is shortened or compressed it becomes wider; its simultaneous length and thickness at different consecutive instants may be represented in two parallel columns, thus:

LENGTH.	THICKNESS.
100	1
25	2
6.25	4
2.78	6
1.56	8
1.	10
.694	12
.51	14
.39	16
.31	18
.25	20

This gives us a series with properties similar to those found in the table given in the earlier part of this paper, only that here we also have the changes represented graphically in the two curves, which would be traced by the changes of position of the two opposite upper angles or corners of the square column of matter in shortening, without change of volume, from a length of 100 to one of only .25.

If $r =$ unit radius (= perpendicular from centre of figure to a side); $p =$ unit perimeter; $V =$ constant volume expressed in terms of r, $x = r$ at any point, $y =$ length, or height of column at any point.

The equation of the curve is $yx^2 = k$, and $k = \frac{2rV}{p}$

The curve is infinite in extent along either x or y, but varies inversely as x^2.

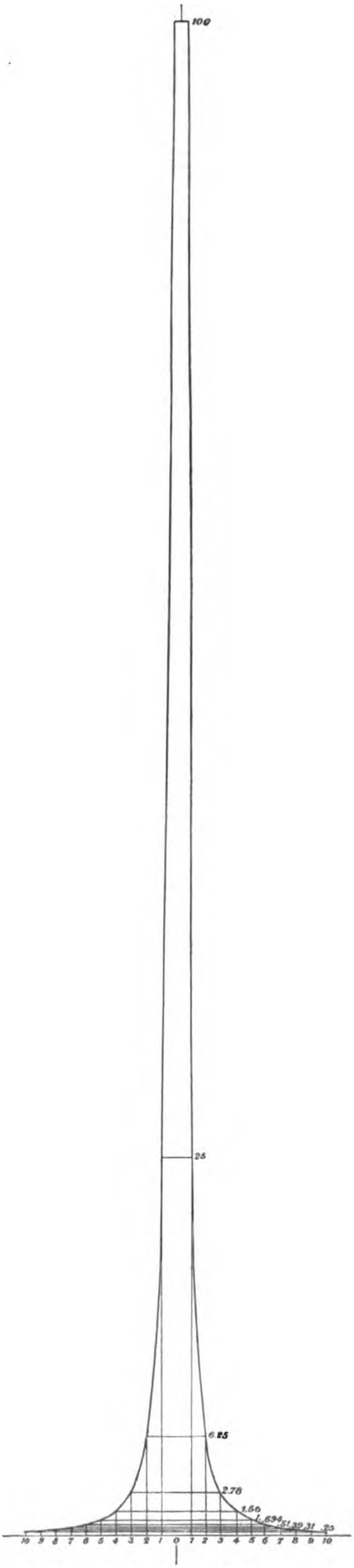
The volume of any cylinder or prism may be expressed in the above terms, as follows: $V = \frac{p}{2r} x^2 y$, when $\frac{p}{2r}$ is constant for any figure call it c. If the column represented by the figure is triangular in cross-section, $c = 3\sqrt{3}$; if square in cross-section, $c = 4$; if cylindrical $c = \pi = 3.14159265+$.

The preceding formula has been very kindly worked out and furnished me by one of my colleagues in the University, Dr. A. P. Brown, who has also very carefully drawn the curve, which is also reproduced in connection with this paper as an accompanying plate.

EXPLANATION OF PLATE I.

CORRELATION OF VOLUMES AND SURFACES.

Asymptotic curve, representing the law according to which the evolution of the forms of organisms has proceeded, and muscular contraction takes place in both voluntary and involuntary muscles, peristalsis in tubular organs, and the changes in the ratios between the surface of the mantle and ends of a cylinder the length and thickness of which are changed by lengthening or shortening it without change of volume. The origin is at *o*; the axis is vertical along which lengthening and shortening of the mass takes place, while the horizontal axis is the one along which is measured the increase or diminution of the thickness of the cylinder during its changes of figure. The numbers to the right and left of *o* represent abscissæ; those along the curve the ordinates. The abscissæ and ordinates are symmetrical in respect to x and y.



RYDER ON CORRELATIONS OF VOLUMES AND SURFACES.

II. The Growth of Euglena viridis when Constrained Principally to Two Dimensions of Space.[1]

By John A. Ryder, Ph.D.

The accompanying observations on *Euglena viridis* were made on material kept alive and growing for a period of several weeks in a Maupas moist-chamber, on a slide under a cover-glass. Under these conditions of restraint the process of cell-division during the multiplication of the organism in question was most peculiar in some respects, if not, possibly, abnormal.

The very thin space between the surface of the slide and under face of the cover-glass remained constant, since great care was taken during the whole period of observation not to disturb the cover. The result of this condition of restraint was that nearly all of the planes of the first segmentations, after quiescence or encystation had taken place, had to proceed as if forced to adjust themselves at right angles to the plane of the narrow, flat space in which the organisms were confined. In the accompanying plate four-fifths of the figures show this tendency to have the cleavage planes placed at right angles or vertical to the plane upon which the culture was spread and confined beneath the cover-glass.

The actively swimming organisms were got out of a gutter at Sea Isle City, on a cold day, March 18, 1891. After my return, the same day, to the laboratory of the Biological School, in Philadelphia, they were placed on a slide as above described. They soon began to show signs of a desire to pass into a resting stage, and many soon became less active and contracted into a motionless spherical form, as shown in Figures 1 to 8, Plate II, soon after which the flagellum was withdrawn, though some of the active swimming forms underwent division directly, three phases of which are shown in Figure 17. Here it is seen that the "head" and "tail" end of the parent become the "heads" of both the resulting young individuals, while the "tails" of the latter correspond to the point where separation or fission of the parent body took place.

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[1] The concluding part of this paper discusses, from a new stand-point, the question of the origin of concrescence of the blastopore as observed in fish-ova especially, and offers an entirely new explanation of the phenomenon.

After encystation and quiescence had been attained, the individuals were observed to grow very considerably in bulk, but as they did so they became more and more decidedly spherical in form, with usually a more or less well-marked gelatinous envelope, as shown in Figure 10. When cleavage was accomplished within such an envelope, one individual, as soon as division was complete, would sometimes actually creep around its fellow and change its position in respect to the latter. Five successive phases of such a change of relative position of two individuals in the same cyst are shown in Figure 16, the individual *a* gradually creeping round its motionless fellow *b*, the "eye spot" of which has also shifted its position. This motion within the cyst was, however, observed very rarely, and only during the earlier days of the experiment.

After segmentation had begun in an encysted or quiescent individual, it was extremely interesting to note the heterochronism of the later cleavages. The first cleavage showed a pair of cells, either naked or in a more or less well-marked capsule, as shown in Figures 13, 14 and 15. Sometimes the second cleavage of the first two cells became at once heterochronous, as shown in Figures 18 and 19, since one of the cells of the first cleavage is seen to have remained unsegmented after the division of the other. Sometimes the two products of the first segmentation furrow divided synchronously, as shown in Figures 20 to 24, 26 and 33, but it is remarkable how differently the four resulting cells are arranged in respect to each other in these cases. In Figures 20, 22, 23, 24, 41 and 42 the first four segmentation products lie on the same plane to which they have been constrained to conform, owing to the pressure of the cover-glass above them and the slide underneath. Occasionally the effect of such constraint is visible in keeping the segmentation upon the same plane, but the segmentation products have been produced by synchronous karyokineses, the axes of which, instead of remaining parallel, as in the preceding cases, have been some how swung round at an angle of 90° to each other. As an example of this, Figure 33 represents a remarkable instance. Figures 22, 23 and 24 are nearly perfect quatrefoils, while 20 and 26 depart slightly from that type with the four cells lying more or less freely in a gelatinous envelope. Figure 21 represents a four-celled stage in a gelatinous envelope which simulates the arrangement of the cells in a typical tetraspore, in which every one of the three faces of each of the four cells that are brought into reciprocal contact or pressure against each other make an angle of 120° in respect to each other, just as the adjacent film surfaces of four soap bubbles of the same size would be similarly inclined to each other. In other cases the resulting masses produced by segmentation are not equal in size, as shown in Figure 19. Figure 25 is a still more marked instance of this, in which segmentation has become heterochronous, that is, some of the cells are dividing more rapidly than others, so that the products of division become unequal in volume. This is even more markedly the case in Figure 32, where an odd number of small cells show that the karyokineses have not divided a single mass into two cells of equal volume, showing that the segmentation has been unequal, as in the segmentation of the meroblastic ova of animal forms. In Figure 44 this is again shown, where the large and round cells in the deliquescing gelatinous envelope are dividing at unequally rapid rates to produce the now escaping very small or young flagellate form of *Euglena*.

This inequality of segmentation may be influenced to some extent by the development within the round resting stages (Figure 11) of stored, coarsely granular, green bodies, similar to chlorophyl granules, and their unequal distribution through the mass, since, as already stated, considerable and rapid growth of the resting stages is often noted. This growth may also extend to and affect some one of the segments of a spore already segmented into four or more segments. This seems to have actually been the case in the instances represented in Figures 34, 35 and 36. The instance represented in Figure 41, however, shows three of the first four segments divided into tetrads while one has remained undivided, which proves that segmentation of one of the first four segments may for some reason be actually retarded. The same thing is shown in a still more singular form in Figure 42, in which two diagonally opposite segments have remained unsegmented, while the two others diagonally opposite have divided synchronously. That this lack of synchronism in division may be eventually overcome is shown, however, by Figure 43, which represents a later stage of Figure 42, in which thirty-two cells are arranged in four groups of eight each, corresponding to the four original masses of Figure 42, or to the four coherent cells of Figure 23.

It will be noticed that wherever the gelatinous envelope is well developed the contained cells tend to separate, and also to become spherical. This is indicated in Figures 14, 19, 20, 21, 25, 26, 32, 41, 42, 43 and 44. Where no gelatinous envelope is formed, and where the cells are in actual contact, a very different form is assumed by them. Here free surface- and interfacial-tensions partly determine the figure of the cells, supplemented by the order and angular divergences and relations of the successive cleavage planes and karyokinetic spindles and the pressure upon and cohesion of the cells to the glass surfaces above and below them. Where the gelatinous envelope for every cell is complete the interfacial-tensions between the cells becomes zero while free surface-tension is everywhere about equal, so that the cells become nearly or quite spherical. These two methods of multiplication of the resting spores of *Euglena* occurred side by side in the living culture on the slide upon which this study is based.

The fourth method of germ-production reported and figured by Stein, one stage of which was observed by me, and represented as seen by the writer in Figure 12, was not followed until the large granular mass at one side of the spore burst to permit the escape of the very minute flagellate spores alleged to be eventually set free.

The four methods of multiplication of *Euglena viridis* are as follows:

(1) The direct fission of the free swimming, flagellate, adult organism, Figure 17.

(2) The passage of the adult into a round resting spore stage, which grows and segments without a gelatinous envelope and eventually produces the adult as at *a* (Figure 35).

(3) The passage of the adult into a round resting spore stage, which grows and segments and at once produces a gelatinous envelope, which eventually deliquesces, and from which very small flagellate young escape (Figure 44).

(4) The passage of the adult into a resting spore stage, or a free-swimming spore germiparous condition, in which a large endoplast *e* (Figure 12) is developed, from which great numbers of exceedingly minute flagellate germs escape, which grow and become creeping amœboid forms, which eventually grow into adult *Euglenæ*.

Of these four methods, the second and third do not seem to have been hitherto described. The second is especially interesting on account of the way in which some of the forms of cleavage it manifests under the conditions of restraint, mainly to two dimensions of space already alluded to, seem to resemble the process of segmentation in the blastoderm of a fish-egg, for example.

The coherent forms of multiplication shown in Figures 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39 and 40 show a surprising variety. Of these Figures 30, 31, 35 and 40 suffered less constraint to a narrow horizontal space than the others. Figure 33 simulates an abnormal form of tetraspore or pollen-grain-formation sometimes met with in plants; the cleavage planes and axes of the spindles of the second segmentation were clearly at right angles to each other. Figures 30 and 31 represent respectively six- and eight-celled masses; Figure 40 is eight-celled, and simulates the stage of the third segmentation of *Amphioxus.* Figures 30 and 34 represent cases in which the cleavage has not been regular or synchronous. Figure 37 represents a peculiar case, showing the cleavage planes and axes of the spindles in the lower two pairs of cells dividing according to the normal scheme of a blastoderm, but the upper half shows heterochronism and an abnormal direction of the third cleavage plane and spindle axis in the upper left hand quarter. Figures 27, 28 and 29 show examples that have divided according to the scheme followed in a segmenting blastoderm of a fish-egg, except that there is a well-marked heterochronism in the cleavages, which diminishes in Figure 29. Figure 36 shows a still more anomalous segmentation; here the lower side has evidently grown most rapidly in bulk, while the upper pair of the original four cells have remained behind in a dwarfed or retarded condition, and have, therefore, also failed to segment as rapidly as the lower pair. Figure 35 represents three very anomalous groups. The segment *a* had the "eye-spot" well developed, and was amœboid and evidently tending toward the condition of the free-swimming form.

Figures 38 and 39 are the most symmetrical and most closely simulate a coherent, flat blastoderm of eight and sixteen cells, as seen in the developing fish-egg. These two figures represent two consecutive stages of the same segmenting mass, and also illustrate in a striking way the tendency of the resulting cells to become discrete along the line I of the first cleavage after the fourth cleavage has been completed. Figure 38 shows slight heterochronism, but perfect synchronism of the cleavage planes is manifest in Figure 39. Here sixteen cells are the result of cleavage planes I, II, III, IV, and there is a tendency toward dissociation of the products of segmentation along the space I, by means of which the sixteen cells are separated into two groups of eight each.

The observations and experimental results recorded above seem to me to be of especial interest in connection with some of the questions raised by the recent interest in experimental embryology and the mechanical agencies invoked in explanation of some of the phenomena of development by Berthold, Dreyer and others. That the actual constraint of the tendencies of growth mainly to two dimensions of space, as here experimentally achieved had something to do with the development of some of the types of coherent segmentation and multiplication of *Euglenæ* figured, it seems to me there can be no doubt. This constraint of growth to two dimensions of space mainly, was also accompanied by other artificial interferences, namely, the exclusion of air from above and below the cells while it could reach them only laterally in every direction. Sometimes, too, it could reach them on one side more favorably than the other. Whether such inequalities in the conditions could have produced some of the anomalies of growth and development here described cannot, of course, be now positively affirmed without considerably more experimental labor.

Similar appearances may be seen in such very low forms as *Merismopedium*, or a similar genus, as I have found in the study of cultures of various other organisms in which the latter appeared, but there is no such tendency to heterochronism in segmentation and coherency as here shown in *Euglena*.

It is easy to see that if such a coherency could by any means be indefinitely maintained even to an eight-celled plakula stage a step would be achieved toward metaphytic, or metazoan development. Whether these results have any such immediate significance in this particular case is exceedingly doubtful, yet we see that certain conditions have seemingly modified the mode of development of the organism, since I failed entirely to find any similar phases of the later stages in other cultures in jars or dishes in which the organism was not subjected to conditions of restraint mainly to two dimensions of space.

What has been abnormally achieved in the preceding experiment upon the segmentation of *Euglena viridis* is achieved normally or physiologically in the case of the segmenting blastoderms of many vertebrates and invertebrates. The segregation of the active protoplasm at one pole or at the surface of the yolk, with which the germinal matter is coherent or even continuous, gives us as one condition the external or upper-surface relation, or that of respiration, while the inner or under-surface relation to the yolk, or that of nutrition, is the other. Growth under these conditions, therefore, proceeds over the spherical surface of the yolk under constraint mainly to two dimensions of space, since the cohesion of the segmenting cells to the underlying yolk, and their interfacial surface-tensions with the latter and each other makes them cohere and conform to its curvature, thus tending to constrain extension due to growth to the curved surface over which lies the growing and yolk-intussuscepting mass. That these forces are interacting in the most uniform manner for a considerable period is proved by the perfectly circular or discoidal and concavo-convex form assumed, and for a time maintained by the growing blastoderm of many forms.

The rate of the increase of the area of a blastoderm growing over one pole of a perfectly spherical yolk is equal to the rate of increase of the square of the chord drawn from the centre of the blastoderm to its rim at successive stages. This gives us a series of areas at successive and equal intervals of time that is finally convergent at the opposite pole of the egg, provided growth is uniform at all points along the margin of the blastoderm, which does not seem to be the case during the later stages of its growth in fish-eggs, but is the case in the latter stages of the growth of the blastoderm in the eggs of birds. For a blastoderm growing over the flattened pole of a prolate spheroid, over one end of an oblate spheroid, or over one side of an ellipsoid, other formulæ must be sought to satisfy the new conditions of magnitude.

It is a singular fact that in many, if not in all cases, the side where the embryo is formed ultimately grows slowest. *This appears to be due to the fact that the blastoderm is thickest at that point and, therefore, intussuscepts materials more rapidly over a smaller area on its under surface at that region than elsewhere. Here constraint to growth is less in the third dimension than at other points in the blastoderm, consequently* *it spreads slowest at the tail-end of the embryo or where it is thickest. It is this condition of inequality of thickness of the blastoderm during its growth which serves to explain the origin of concrescence,* which we thus see receives a mechanical and adaptive explanation. The phenomena of concrescence are thus influenced indirectly rather than directly by inheritance. Only in those cases where the embryo is very soon developed within the margin of the blastoderm and where concrescence is soon completed, does the rate of the growth of the blastoderm again become uniform so as to travel over or intussuscept the yolk at a uniform rate at all points along its circular margin. In these cases the blastoderm will be found to have again become uniformly thick at its margin, so that intussusception goes on uniformly.

If the blastoderm is ten cells deep at the point where the embryo is formed, and only two cells thick at the non-embryonic part, it is clear that it will take five times as much protoplasmic matter to build up its thickness in the embryonic region as in the non-embryonic portions. If this is so, the same volume of segmented or cellular living matter in the embryonic region can cover only one-fifth the area of yolk surface that is covered by the thinner stratum of non-embryonic cells in the same time. The result is that concresence *must* set in at the tail-end of the embryo, since the blastoderm is spreading faster at the non-embryonic portions of its rim, owing to the inequality in the rate of formation of the thickness of the embryonic and non-embryonic parts of its margin. The first is growing in length breadth and thickness, the latter mainly in length and breadth, in other words, growth goes on in the embryonic region in three dimensions of space, whereas in the blastodermic region there is restraint of growth mainly to two dimensions of space. Concrescence in a fish-egg, for example, is therefore seen to be an effect of the unequal growth in thickness of the blastoderm under the control of "hereditary influences." Concrescence is, consequently, to be regarded as an adaptive effect rather than as a cause, under the condition that inter cellular and intra-cellular metabolism goes on at varying rates in three dimensions of space at different points in the blastoderm, since it is a self-evident truth that if matter is extended respectively at an equal rate in three dimensions of space or in two dimensions of space it will be extended upon a plane surface, in the first case, in the ratio of the square of the cube root $(\sqrt[3]{v})^2$ of its volume, and in the second case in the ratio of the square of the square root of its volume or $(\sqrt{v})^2$. The variations of the rate of growth in three dimensions of space are infinite in number, so that there may be an infinite number of ratios realized between $(\sqrt{v})^2$ and $(\sqrt[3]{v})^2$ where the average volume of the cell is the unit of volume, and when the dimensions of a cellular mass are referred to, each cell of which covers a unit of area, on a plane underlying the latter. Variations from the simultaneous and uniform rate of operation of the forces of growth in the three dimensions of an organism, therefore, determine its shape or figure. The workings of the forces that we sum up in the aggregate as "heredity," control the relative proportions of those simultaneously developed ratios of the dimensions which determine the figure, and, therefore, the distribution of matter, and consequently of energy in the growing organism. We here encounter, bared of every extraneous issue, the very kernel of the dispute between the followers of Lamarck and Weismann. It may now be asked if heredity controls the distribution of matter and consequently of energy in the developing organism, what is it that controls "heredity" itself? Since heredity is only a name for the result of the summation of the effects of a vast series of phylogenetic agencies or energies that have operated from within organisms adaptively or according to the chemical and dynamical laws of the motion of particles and masses under the physical constraint of outer cosmical conditions, of which only the completely realized adjustments seem to have been preserved, it remains to consider the way in which a mechanism may be built up so as to respond in a certain orderly way to the changes of outer conditions during development. The achieved complexity of a type means the conservation of so much energy, through a specific mechanism or organism, in the form of "vital" activity which can offer the sum of its powers as a specific form of reaction or resistance in response to a change of conditions. If the sum of the specific form of the energies of reaction of an organism $A = \Sigma$, then if it be brought under the influence of diverse or varying outer conditions, C_1, C_2, C_3, successively, its responses will be such that Σ will tend to become Σ_1, Σ_2 or Σ_3, as the case may be. In other words, a new resultant of the interacting energies will be produced every time that Σ or C is varied. This variation in the mode of dissipation of energy must react upon the figure of the organism, as was proved or rendered self-evident for the very simple case of *Amœba proteus* in the preceding paper. In this way only is it conceivable that variations of form could arise that were in a condition of dynamical adjustment of function in relation to outer conditions. In other words, "natural selection," robbed of its metaphorical sound, is only another way of expressing the fact that a dynamical process of adjustment has been successful. In this way, also, it becomes possible to bring the processes of evolution under the domination of the great principle of the conservation of energy. Viewed in this way, "heredity" itself is only an effect and is at last dominated and directed in its onward or progressive complication by the laws of the conservation of energy. The progressive or superpositional, substitutional steps of morphological evolution are a further and capital proof of this conclusion. What the mechanism of heredity is, or what the laws and causes of its operation are, remains to be discovered by an elaborate and connected study of the phenomena of organic growth and the mechanisms and correlations of the same, and not by the assumption of the existence of unknowable as well as undiscoverable *gemmules*, *plastidules*, *germ-plasms*, etc. Such devices will unquestionably be consigned in due time to the same limbo as has befallen astrology, alchemy and the doctrine of signatures. The physical basis of life is admittedly very different in different beings, but this does not compel us to resort to a system of conceptions that are too intricate and mysterious for the human mind to grasp, or from which it is impossible to derive an intelligible mental picture of the facts. If the facts look as if gemmules were needed to give our views consistency, we are confronted by insuperable difficulties that are no less insurmountable with a germ-plasm, which I believe, with Lloyd Morgan, to be a mischievous fiction that takes a part of the germinal matter of an organism to represent the totality of its phyletic potentialities. Since we know nothing whatever of the development of this so-called germ-plasm except as it develops within the cytoplasm, to assume that it is the sole and only agency controlling the order and mode of development of the organism, it seems to me is making an assumption that cannot, in spite of every detail of experimental evidence yet offered, be accepted without committing oneself to an untenable position. We can know simply nothing of organisms unless they are regarded as complete wholes and as complete mechanisms. To pick out some one part as the essential elements of the mechanism of development is as absurd and unscientific as the efforts of the Weismannians to tacitly evade and deny the validity and universality of the principle of the conservation of energy, when they tacitly deny that dynamically adjusted, or developed characters can be inherited, since every known character of every known organism had to be thus acquired; how, *they* have not told us. Certainly not by the miraculous capers of a germ-plasm standing in the middle of a mass of cytoplasm, or cells like a *prestidigitateur*, and ordering where this or that variation of a pseudopodium, flagellum, process, outgrowth, etc., was to be extended, when, *presto*, it immediately appeared. No, every such act means the expenditure of energy and consequently of motion on the part of the whole or part of the protoplasmic mass involved. If an energy of motion of living matter had to be expended when the character first appeared in some ancestor to produce it, how is it possible to suppose that that energy of motion was not set up by some other motion, stimulus or impulse developed by the combined action of powers developed from forces acting both from without and within? Whenever the Weismannians can offer an adequate reply to this last question I will cease my attacks upon their unscientific position, that is at variance with the whole spirit of modern scientific inquiry.

Much evidence has recently been developed that renders Weismann's position untenable. Meanwhile the evidence becomes more satisfactory and conclusive as affording proof of the dynamical doctrine of evolution. That the known effects of cultivation upon fruits and seeds in bringing about an increase of size should be wholly due to "selection" is distinctly not proved, because it must first be shown that seeds of increased size were not produced by the conditions of better nutrition afforded by culture, and, therefore, under conditions wherein the organism as a whole had a better opportunity to display the sum of its energies in growth. If it is retorted that this better condition for the display of the energies of growth is itself an admission of the operation of selection, it puts "selection" in the position of a controller and apportioner of the matter and energy of the universe, in so far as that matter and energy is related to living beings. If it is admitted that the action of "natural selection," as I believe Mr. Darwin intended, effects only the preservation of those organisms that are best fitted for existence, and permits them to transmit their peculiarities hereditarily to offspring, then it becomes a truly important agent. But to affirm that this selective process can in and of itself originate new features and produce variants from a given type, without the direct interference of some new cosmical condition never before experienced by any individual of the species, it seems to me is going beyond anything that the evidence yet in our possession will warrant. The secular variation of the individual even has by no means yet been proved to be due to something contained from the beginning if its existence in the germ from which it arose. So long as this secular variation of the individuals of a species, from the germinal to the germ-producing condition has not even been adequately studied, especially from the standpoint of the direct effects of variations of the activities of the environing and conditioning cosmical energies, there can be no other safe course to pursue than to suspend judgment until new and conclusive facts are in our possession.

EXPLANATION OF PLATE II.

Transformation and segmentation of *Euglena viridis* when constrained to develop mainly within two dimensions of spaces.

Figures 1–8. Free-swimming *Englena viridis*, gradually rounding itself off and passing into the resting or vegetative stage.

Figure 10. Resting *Euglenæ:* one just divided and empty cysts formed by others.

Figure 11. Resting *Euglena* encysted and filled with large green granules.

Figure 12. Resting *Euglena* with large nucleus, representing the stage figured by Stein as giving rise to very minute young.

Figure 13. A *Euglena* in division into two young, with "eye-spots."

Figures 14 and 15. Encysted *Euglenæ* divided into two.

Figure 16. Five stages, showing two *Euglenæ* in a cyst creeping round each other in the direction of the arrow.

Figure 17. Three stages in the process of division of a free-swimming *Euglena*. The opposite ends of the parent become the "heads" of the young.

Figures 18 and 19. An encysted and a naked quiescent *Euglena* divided into three young cells.

Figures 20–24. *Euglenæ* in resting condition, encysted and unencysted, showing different forms of division into four young.

Figure 25. Encysted *Euglena*, showing unequal division into five young.

Figure 26. *Euglena* encysted and divided into four.

Figures 27–37. *Euglenæ* in the resting stage, showing various forms of segmentation.

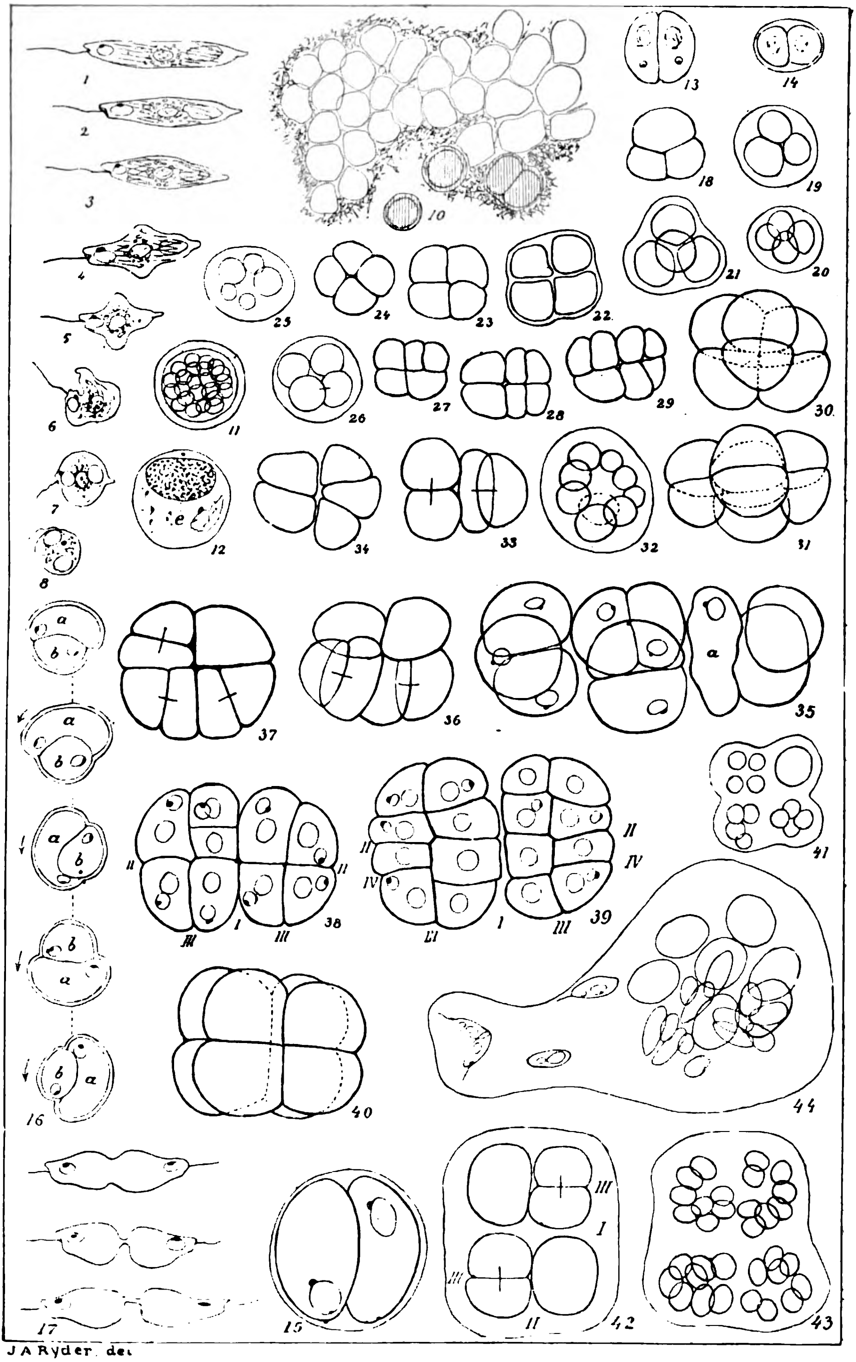
Figures 38 and 39. Two consecutive stages of segmentation of *Euglena* under constraint mainly to two dimensions of space, showing a more or less discoidal and symmetrical cleavage.

Figure 40. A symmetrical form of segmentation of *Euglena* somewhat like a holoblastic, segmenting metazoan egg after the third cleavage.

Figures 41 and 42. Heavily encysted *Euglenæ*, showing marked heterochronism in their segmentation.

Figure 43. Heavily encysted *Euglenæ* that lie in four groups, the result of the equal segmentation of four parent cells.

Figure 44. Heavily encysted *Euglenæ* that are segmenting very unequally. Some of the young are already flagellate and ready to escape from the cyst.



J A Ryder del

RYDER ON EUGLENA.

III. Descriptions of Three New Polychæta from the New Jersey Coast.

By J. Percy Moore,
Instructor in Zoölogy.

The descriptions of the three species of annelids here presented are based on specimens forming part of a small collection made at Sea Isle City, during the summer of 1892. A full list of the species collected will appear in the forthcoming report of work done at the Marine Laboratory. The descriptions of several apparently new species of Syllidæ are withheld, pending a more thorough study of that large group.

Clymenella elongata (*n. sp.*).

Plate III. Figures 1a–m.

Named *elongata*, because the species is much more elongated than any specimen of *C. torquata* (Leidy) Verrill, that I have examined. The single specimen collected measures ninety millimetres in length, and two millimetres in diameter. The body is of almost uniform diameter throughout, but is slightly enlarged in the middle region.

Head flattened dorsally. The cephalic plate oblique, inclined to body axis at an angle of about 45°; broadest posteriorly, its borders convex. A low median dorsal ridge, most prominent anteriorly, where it terminates in a broadly rounded, somewhat projecting, margin. The flattened areas on each side of this are marked posteriorly by a pair of short longitudinal grooves, separated by a narrow ridge. Posterior marginal fold broad, thick, and prominent; its free margin obscurely lobed: lateral folds highest anteriorly, strongly flaring, the free margins not deeply lobed: anterior fold nearly perpendicular to body axis, its margin four-lobed: lateral folds separated from anterior and posterior by deep sinuses.

Buccal segment prominently swollen behind mouth. Proboscis thrown into rounded folds, and not ribbed as in *C. torquata.*

There are twenty-two setigerous segments (perhaps more, as the specimen had been broken in the middle, and no notes were taken at the time), all of which bear both capillary setæ and rows of hooked uncini. The latter are arranged in each segment in a pair of linear transverse series of fifteen to twenty, on narrow raised lines, which become broad and swollen on the posterior segments; their position is latero-ventral. The capillary setæ are fixed in fleshy papillæ attached to the dorsal ends of the uncigerous lines.

First setigerous segment very obscurely marked off from buccal, so that the distinction was at first overlooked. The first, second and third setigerous segments are slightly longer than the fourth and fifth, which are the shortest of the series. The anterior border of the fourth bears a thickened collar, which embraces the segment next in front. The sixth is equal to the third; with the seventh begins an increase in length, which continues to the twelfth, this being about as long as the second and third together. In this region the setigerous papillæ and uncigerous lines have shifted from the anterior to the posterior ends of the segments, where they occupy prominent swellings. From the thirteenth to the seventeenth segments there is a gradual shortening, the seventeenth equalling the eighth; the eighteenth to the twenty-first again lengthen, the twentieth and twenty-first being as long as the twelfth, these three being the longest segments of the body; the twenty-second is again shorter. The anterior and middle segments are nearly cylindrical; the posterior (behind the seventeenth) are narrow anteriorly, and expand to their greatest width near the posterior end.

There are two non-setigerous pre-anal segments, the most anterior being three-fourths the length of the last setigerous one; this segment is of an elongated ovoidal shape. The last pre-anal segment is very short—a mere ring—and bears the anal funnel, which was contracted in the specimen described, but bears around its margin about twenty short papillæ, which surround a conical elevation at the summit of which the anus is situated.

Capillary setæ are of three forms, that appear to be intermingled in the fasciculi. The most common have the gracefully-curved and rounded stem bordered on either side by a narrow edge or blade, which extends almost to the acute, curved point. Others are slender and pointed, with a single thin margin on one side, broadest at the base, and ending some distance from the tip. The third form is less numerous, but very long and excessively slender; the stem is doubly bordered by fine spines disposed in two opposite rows, and spreading slightly in a common plane; the appearance being that of a very long narrow feather. These setæ were described from the twentieth segment.

The uncini are deeply imbedded in the tissues, the hooked ends only projecting from the surface. The stems of the ventral uncini are long and curved, shorter and straighter on the dorsal ones; they are internally attached to a strong ligament, and just beneath the skin enlarge to form a broad shoulder, at which point the terminal piece is readily detached. The hooked end bears a strong decurved tooth, supported at its base by three smaller ones (four on sixth segment), all of which have a fibrous structure. Within the concavity of the hook arises a brush or beard of slender hairs, most of which curve gracefully upward on both sides of the principal tooth. On the sixth segment the beard appears to spring from the base of the large tooth itself; but this point has been insufficiently studied, and I was unwilling to further sacrifice the single specimen to the description.

Described from a single specimen collected on the mud-flats of Ludlam Bay, New Jersey, August, 1892. The species is a tube-dweller, and was found with *C. torquata*, *Maldane elongata*, *Amphitrite ornata*, *Drilonereis longa*, *etc.*

Eulalia lobulata (*n. sp.*).

Plate III, Figures 2a to 2f.

Named *lobulata* from the lobulated appearance of the peculiar tentacular appendages.

The sixty-eight anterior segments measured thirteen millimetres in length.

Body depressed and broad; segments very short, bearing prominent parapodia, which are much crowded anteriorly. Posterior segments proportionally longer.

Head nearly one-fifth broader than long; its greatest width well behind middle; lateral prominences rather sharply rounded, almost angular. Posterior border broadly concave, with prominent lateral angles; antero-lateral outline deeply concave; anterior outline slightly convex, its angles rounded.

Anterior-paired antennæ of equal length, somewhat flattened, narrowed toward the base, broadest beyond the middle, and suddenly tapering to a blunt point; with a sub-terminal emargination, deepest on the ventral pair. Ventral pair of antennæ inserted well on the ventral surface of head, and posterior to the dorsal pair, the origin of which is on the antero-lateral angles of the head. Median antennæ arising posterior to middle of head just in front of its greatest width; its base contracted and diameter slightly increasing toward middle (the terminal portion is missing).

Eyes dark brown, situated near postero-lateral angles of head, their long diameters less than three times in median length of head; external outline nearly straight; internal strongly convex; longest diameter antero-posterior.

Head with a median ventral ridge, which becomes broad and flat anteriorly. Buccal segment truncate; its margin crenulate.

Tentacular cirri of first segment incomplete, the part present about equal to head in length, and of nearly uniform diameter. The species is best distinguished by the possession of peculiar lobed appendages near the distal extremities of the tentacular cirri of the first two setigerous segments. The ventral pair of the first setigerous segment possess short basal and stout terminal articles one and one-third times the length of the head; following a slight constriction about the middle of the latter piece is a prominent swelling, which bears on the ventral side the lobulated appendage referred to above, and beyond which the cirrus ends in a short, blunt point. The dorsal cirri are borne on strongly curved basal articles; the terminal portions are long and stout, but, unfortunately, incomplete in the specimen. A slight thickening near the end of the more perfect one may indicate the presence on these also of the lobed appendages. The dorsal cirri of the next segment, which bears a well-developed parapodium, are long and slender-pointed; length about two and a half times that of the principal piece of the second ventral cirrus. This cirrus bears at a point slightly more than one-third of its length from the tip a distinctly pedunculated body, which is similar to, but more conspicuous than that borne by the second ventral cirrus. These lobulate appendages are deserving of further study.

The branchiæ are foliaceous; those of the middle region are broadly heart-shaped, and much longer than the ventral cirri, which are closely appressed to the parapodia and attached obliquely.

The stems of the setæ bear short, rather stout, sharp-pointed terminal pieces, which are delicately toothed along the inner curved margin; the terminal end of the stem is slightly thickened, and delicately toothed and fringed along the margin.

Described from a single incomplete specimen collected among *Molgula.* Ludlam Bay, New Jersey, August, 1892. In the figure of the parapodium (2c) the setæ are represented too large and heavy.

Eracia brevicornis (*n. sp.*).

Plate III, Figures 3a to 3h.

Named from the character of the dorsal-paired antennæ. A complete specimen of sixty-seven segments measures fourteen millimetres in length. Form rather slender; dorsum convex, elevated.

The segments increase gradually in width from the head to about the twenty-fifth, remaining equal as far back as the fortieth, behind which they gradually narrow to the anal segment.

Head longer than broad; as eight to seven: its greatest width a little behind middle; there prominently rounded; constricted and concave anterior to this and tapering anteriorly; anterior border straight, its angles nearly square; posterior margin slightly concave. The dorsal surface presents a well-marked depression, extending from the posterior border nearly to the base of the median antenna. A slight transverse constriction is noticeable just behind the anterior antennæ. Ventral pair of antennæ stout, with short basal articles; about three-fifths of length of head. Dorsal pair very much reduced, being mere pointed tubercles; their length about one-third of diameter of eye. Median antenna arising from middle of head, slender and tapering from a broad base; length more than three-fourths that of head. Eyes large, brown, oblong-elliptical in shape, situated close to lateral margin of head, and midway between median antenna and posterior margin. Buccal segment pouted forward in the middle.

Tentacular cirri with terminal articles missing, except a ventral one of the second segment; this one slightly longer than head, and tapering rather suddenly to a slender tip. The dorsal cirri of the second segment have an elevated insertion, the basal article being stout.

Dorsal cirri (branchiæ) of remaining segments foliaceous, ovate-lanceolate in shape, with base scarcely indented; about one and two-fifths to twice the length of corresponding ventral cirri, which are oblong, with blunt, rounded tips, and scarcely flattened. Dorsal cirri much more easily detached than ventral. Dorsal and ventral lobes of parapodia about equal in development, both bearing setæ.

Setæ numerous, similar on all segments except the second, which bears a few short ones; longest on middle segments. Stem slender and curved, somewhat enlarged and bi-lobed at the end, the dorsal lobe being much the larger, and minutely toothed on the margin; ventral lobe a single sharp, slender and curved tooth. Terminal piece slender and more or less strongly curved, sharp-pointed, and finely serrate along the concavity of its curve; attached to stem by a delicate membrane.

Color in alcohol dull yellowish, the dorsal surface of head, tentacular cirri, bases of parapodia, and a broad zone on each segment thickly dotted with minute dark brown specks. On the back narrow immaculate lines separate the punctated zones, producing an appearance of annulated color distribution. Cirri brown.

Described from a specimen collected among *Botryllus*, in Ludlam Bay, New Jersey, August, 1892.

EXPLANATION OF PLATE III.

FIGURES 1*a–m*. *Clymenella elongata*.

Figure 1*a*. Dorsal aspect of head and anterior five setigerous segments. ×6½*d*. The protruded proboscis, the cephalic shield, and the collar on the fourth setigerous segment are shown.

Figure 1*b*. Dorsal aspect of posterior region of the body, showing the anal funnel and fringe, the non-setigerous pre-anal segments, and the last two setigerous segments. ×6½.

Figure 1*c*. Full outline of anal segment. ×6½.

Figure 1*d*. Dorsal view of head tipped forward to show lobulation of the free margins of the cephalic shield. ×6½.

Figure 1*e*. Twelfth setigerous segment. ×6½.

Figure 1*f*. Profile of the head, showing extended proboscis. ×6½.

Figure 1*g*. A ventral uncinus from the twentieth setigerous segment—terminal portion. ×330.

Figure 1*h*. A dorsal uncinus from the twentieth setigerous segment—complete. ×330.

Figure 1*k*. A dorsal uncinus from the sixth setigerous segment—complete. ×330.

Figure 1*l*. A ventral uncinus from the sixth setigerous segment—terminal portion. ×330.

Figure 1*m*. Three forms of capillary setæ. ×800.

EXPLANATION OF PLATE IV.

FIGURES 2*a–f*. *Eulalia lobulata.*

Figure 2*a*. Dorsal view of head and anterior two setigerous segments. ×38.

Figure 2*b*. Ventral view of head and anterior region of body. ×38.

Figure 2*c*. A parapodium from middle region of body (twenty-first segment), seen from behind. ×40.

Figure 2*d*. A segment from the same region seen from above. The parapodium of the right side is omitted, and the bases only of the setæ on the left are shown. +40.

Figure 2*e*. A seta showing only the blade and terminal portion of the stalk. ×300.

Figure 2*f*. The articulation of a seta more highly magnified. ×800.

FIGURES 3*a–h*. *Eracia brevicornis.*

Figure 3*a*. Anterior region from dorsal aspect. ×38.

Figure 3*b*. Parapodium from middle region of body, from behind. ×38.

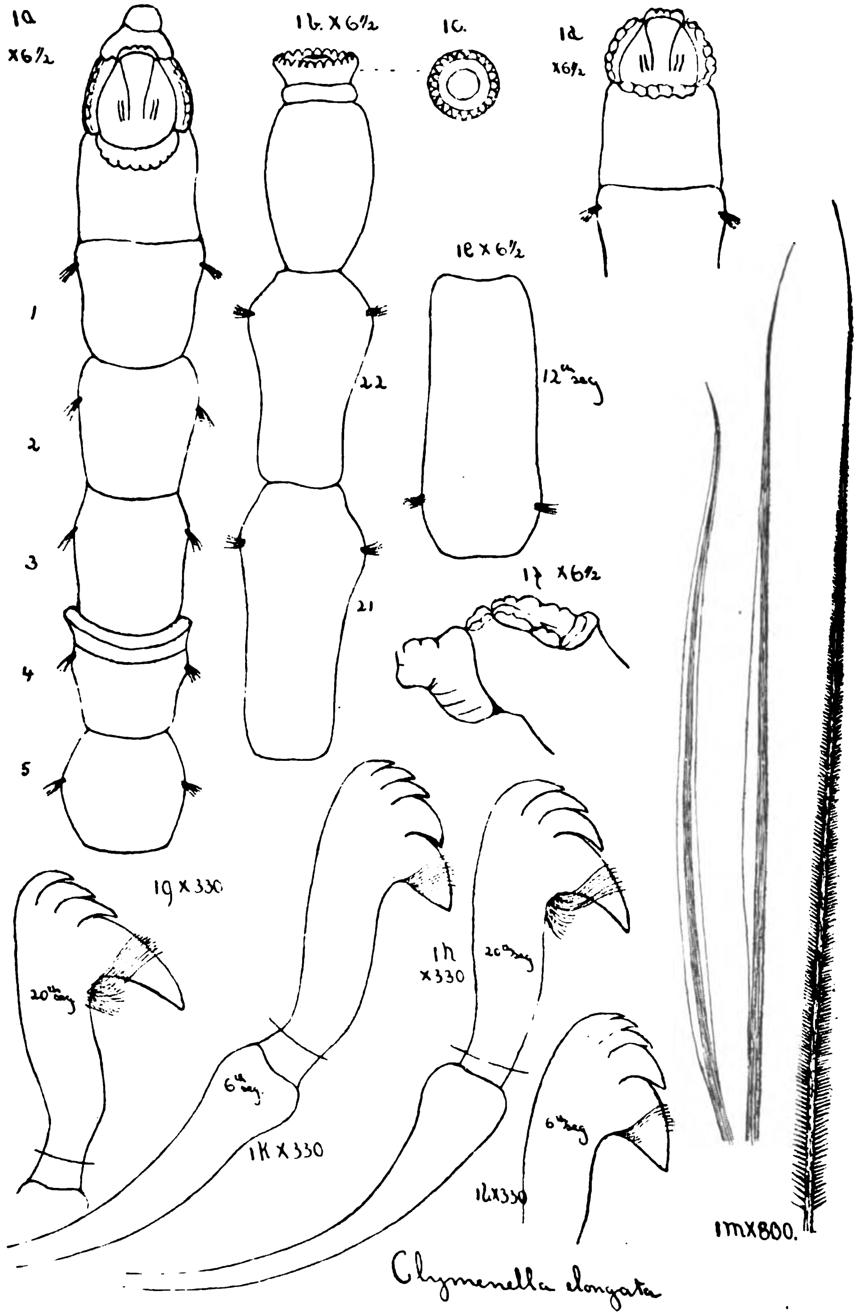
Figure 3*c*. Outline of head from ventral aspect, showing form of buccal segment. ×38.

Figure 3*d*. A parapodium viewed from ventral side. ×38.

Figure 3*e*. Outline of anterior border of head, showing the form and position of the cirri. ×38.

Figures 3*f* and *g*. Two views of the articulation of stalk and blade of a seta. ×800.

Figure 3*h*. Terminal portions of two forms of setæ. ×330.



MOORE ON NEW POLYCHÆTA.

Contents of Vol. I, No. 2.

On the Embryos of Bats. By Harrison Allen, M.D.

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On the Embryos of Bats.

By Harrison Allen, M. D.

In the course of a recent study of the Chiroptera I was so fortunate as to obtain a number of embryos. I will briefly describe in this communication, as a preliminary study, the arrangements of the limbs and the disposition of the several parts of the trunk to each other; and after this is done, to invite attention to the general proportions of the limbs. The original intention was to make a careful study of all individuals, but sufficient interest was found in the study of the superficies to warrant, it was thought, the study of these parts in the form of a separate fascicle. So far as I know, the manner by which the exceptional shape of the bat can be made to complete the outline of an elliptical figure, which is so commonly present in the vivaparous vertebrate, has not been made the subject of special scrutiny. In the Primates the head of the fœtus is ordinarily flexed upon the neck and the limbs are bent in various ways upon the trunk. A like disposition is met with in the Chiroptera, and I can recall no other mammalian forms in which it is met with in an equal degree.[1]

The parts which appear to be in common in the Primates and Chiroptera are the relatively large size of the head, as compared with that of the trunk and the great length of the limbs; for even the posterior limbs of a bat are large, when the size of the trunk is taken into consideration.

Since nothing was known of the age of the specimens, the degree of maturity will be indicated by measurements. It is assumed that most of the embryos were near term.

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[1] In rodents the hind limbs and tail are bent forward on the abdomen in a manner quite the same, though in less degree, as in the bats. The reader should also compare the figure of *Galeopithecus*, page 30—here a disposition of the limbs is seen bearing a superficial resemblance to that of the bats.

Each specimen exhibits the following features: The upper end of the ellipse is the occiput or crown; the lower, the pelvis; the sides, the forearm and manus. On one side the parts are as already named; on the other they are disposed, so as to press more to the front, which is made up of the face and the folded legs and feet. The back exhibits the dorsum of the trunk and shows traces of the vertebral column and the scapulæ. The auricles are pressed downward or forward; the thumb and feet are well developed; indeed, are relatively larger than in the adult. The loin is bent forward, so as to bring the legs in front of the trunk.

The entire series numbers but sixteen specimens and represents examinations of extensive suites of individuals. The ratio of the occurrence of gravid females in the collections of our museums is so small that it would be useless to compute it. Adult bats appear to be secured for most part after the breeding season is over. Notwithstanding the paucity of examples of bat embryos, and the limited area from which they have been gathered, it was thought their description would be acceptable to biologists.

The genera (with one exception) are either represented in America[1] or are peculiar to it, and include

Rhinolophus	Rhinolophidæ
Mormops	Phyllostomidæ
Brachyphylla	
Artibeus	
Lonchoglossa	
Glossophaga	
Molossus	Molossidæ
Atalapha	Vespertilionidæ
Adelonycteris	
Vespertilio	
Vesperugo	
Rhynchonycteris	Emballonuridæ

Rhinolophus affinis (Plate V, Figure 1).

The embryo of this species is in an early stage, earlier indeed than in any specimen previously observed.

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[1] One young of *Desmodus* (shown in Plate VI, Figure 12, for the expended wing) is not included in the list.

The general characters of the mammalian fœtus are present, with the exception of the broad form of the mass which represents the undifferentiated anterior extremity it would be difficult to assign to it a shape or size in any marked way differing from the posterior extremity.

The tail is somewhat longer than the posterior extremity.

Length 6mm; width 3m.

Mormops blainvillii (Plate V, Figures 2 and 3).

The embryo is in earlier stage than other leaf-nosed forms. The parts are in bad condition. Length, 15mm; width, 7mm. Head inclined toward the venter and to the right; the members all lie to the left side of the head. The tip of the tail, if produced, would lie also well to the left side; the vertebral column not being twisted. The left arm is superficial, but the right is withdrawn within the ellipse, and lies against the chest; the feet are doubled up in front of it; they are thus separated from the trunk, the left foot being in front of the right. The digits in both wings are extended.[1] This fact is especially noteworthy for the right digits; that is to say, they are straight notwithstanding their cramped position. The tail extends the entire length of the interfemoral membrane.

The forearms do not reach beyond the crown of the head and are on one level. The wing when expanded (Plate V, Figure 3) exhibits differences, both in relation and proportion, as compared to the adult. The thumb is in serial line with the remaining digits—its primitive position—and forms the outer member of the manus. In the adult the thumb lies in front of and parallel to the second digit. The relative lengths of the digits are different from the adult. The third digit is scarcely longer than the fifth.

Brachyphylla cavernarum.—(Plate V, Figures 6, 9, 10; Plate VI, Figure 11.)

Two embryos at about term were secured from this species, one of which will be fully described and figured. The length of the ellipse is 30mm., the width 18mm. Viewed from in front (Plate V, Figure 9) the ellipse shows the head inclined slightly to the left, the left manus and forearm placed high upon the side of the head, the extended thumb indeed reaching the occiput. The third digit is straight to last phalanx, which is deflected. The left manus is forced downward so that the upper end lies under the auricle, and the entirely deflected phalangeal series lie at the lower end of the ellipse. In the interval between the mani appears the very large left foot, the first digit being widely separated from the others.

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[1] The words extension and flexion in this sense are in opposition, as are the words abduction and adduction. These last named are used in describing the movements of the digits in opening and closing the wing.

The second figure (Plate V, Figure 10) is drawn from the same specimen as the foregoing, but foreshortened from beneath, and exhibits the perfectly straight disposition of the pelvic structure, together with the right manus. It is noticeable that the phalanges are much deflected forward, where the digits, with the exception of the thumb, are closely adpressed. While unfolding the wings and legs it is observed that no torsion of the body is present; the right foot lies directly against the body, while the left foot is in advance. The first toe of each foot is abducted. The interfemoral membrane extends across the space between the legs at the ankle. Length of head, 9 mm.; length of foot, 9 mm.; length of thumb, 6 mm.; no deciduous teeth are present, but the shapes of the permanent teeth are seen as in *Artibeus*.

Plate VI, Figure 11, exhibits the right wing and both inferior extremities, and the interfemoral membrane in the position of flight. The thumb is in the acquired position, namely, of palmar flexion; the numbers of elements in the digits are as in the adult, while the characteristic lines in the third and fourth digital interspace are present.[1] I may here mention that the small tail observed by me (Proc. Acad. Nat. Sci. 1889, p. 320) in the adult of *Brachyphylla* was carefully sought for by Mr. P. C. Moore, but no trace of it was found. The rudimentary noseleaf is precisely as in adult, but the warts both on the muzzle and chin are scarcely discernible. The tragus is without serrations.

The second embryo (Plate V, Figure 6) differs from the first; the right forearm is parallel to arm and inclined backward so that it lies obliquely across the side of the ellipse, the elbow being on the level with the greatly depressed muzzle, while the wrist is on the occiput,—the thumb being in the primitive position, but placed backward so that it almost touched the scapula. The manus otherwise is displayed on the crown, the fingers lying parallel with one another and traversing the crown, the third digit reaching the tip of the left auricle. The fifth digit is close to the forearm and lies parallel with it.

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[1] The artist unfortunately has failed to draw these lines; they are seen in *Natalus*, p. 14.

The left upper forearm is also oblique, but is placed further down on the side of the ellipse, from the front of the trunk to just below the auricle. The forearm is sharply flexed, and the manus closely adducted. The thumb is not visible. The phalanges of the third, fourth and fifth toes are disposed to be adducted, a disposition most marked in the third digit. The lower half of this embryo had unfortunately been removed before the disposition of the limbs had been studied. The dimensions of the ellipse were essentially the same as in the specimen first described.

Upon unfolding the wing membrane it is seen that the left thumb is in the primitive position and lodged in the deep groove made by the bending of the head on the trunk.

		No. 1 mm.	No. 2 mm.	Adult mm.
Length of head,		71	16	30
Width " "		10	10	20
Length of trunk,		22	22	58
" " forearm,		16	15	66
First digit	metacarpal,	1		3
	phalanges,	4		12
Foot,		10		12
Tibia,		6		28

The internal basal lobe of the auricle is scarcely discernible, but in the adult this equals one-third the width of the attached part of the auricle.

The nose-leaf is distinct, though without some of the details seen in the adult. Thus the minutely crenulated upper free surface, which can be discerned with care between the nostrils, is absent. In the adult a shallow depression is seen overlying each nostril. This is also absent in the embryo and in the young active form. The vertical internarial ridge is also absent. Thus the difference in the form of the nose-leaf of the embryo and the adult are more marked than in *Artibeus*.

Artibeus perspicillatus. ♂ (Plate V, Figures 7 and 8.) Length, 35mm. Greatest width, 23mm. Length of body, 30mm. The right manus with fourth digit almost entirely concealed; the third digit not flexed and reaches nearly to the lower border of the ellipse, the end of the second digit without fusiform swelling; the forearm is vertical—*i.e.*, parallel with the ellipse and carries the manus well up almost to the level of the crown of the head. The left manus concealed excepting the phalanges of the fifth digit, which are seen extending obliquely across the ellipse below the straight, sharply flexed head. The forearm is displayed nearly its entire extent, but lies below the level of the downward pressed auricle in the deep recess between the depressed head and the trunk, above the left leg; all the remaining portions of the manus are closely adpressed. The trunk below the thorax is abruptly bent forward, the left leg and part of the left foot alone being exposed. The head is bent forward in a perfectly straight line.—The wing membrane and the hind limbs being unfolded, it is found that the right foot is flexed on the leg, the dorsal surface presenting outward, and the plantar lying in part on the right elbow and part on the abdomen. The thumb was bent in, and laid close to and parallel to the third metacarpal bone. It is represented in the figure as drawn out. The pollical border of the left manus is rotated inward, so that the first, second, third and fourth digits lie against the fifth, which remains unchanged in position and appears on the anterior surface of the ellipse.

The right auricle is pushed up while the left auricle is pressed down against the head.—The denticulations on the outer border of the tragus are distinct as in the adult. The glands at the side of the nose-leaf as in the adult, but flattened. This gives the appearance of a crenulated border to the region. The lower border of the nose-leaf is without definition. In other respects the nose-leaf is exactly the same as in the adult.

A few minute sparsely distributed hairs are seen on the occiput, but practically the specimen is hairless.

The wing membrane is marked as in the adult. It is attached nearly to the distal end of the metatarsus. The position of the calcar is distinctly seen. The interfemoral membrane is without incision, and is much longer than in the adult. The free margin unites the two metatarsi about midway between the ankle and the phalanges.

The angle of the mouth extends to a vertical line which, if continued, would intersect the external canthus. No deciduous teeth are present. The shapes of the crowns of the permanent set are distinctly seen.

The auricle is narrower and more pointed than in the adult —the internal basal lobe much the same, but the external basal lobe indeterminate. It lapses without demarcation into the single scallop.

A second individual exhibited an ellipse much smaller than the one above described. It is 24mm in length and 15mm in width. It resembles the larger specimen in all respects, excepting that the toes of the right foot are separated—not in a natural way but as though from a force operating from without (as within the wall of the uterus) had forced the toes from each other, and the right foot was pressed with its dorsal surface against the trunk. The vertebræ were so distinctly seen beneath the integument of the dorsum that they could be counted with accuracy. The flexion to throw the hind limbs forward on the front of the trunk took place abruptly between the sacrum and the lumbar vertebræ. The sacrum and the pelvis thus formed the lower part of the ellipse.

	LARGE SPECIMEN. mm.	SMALL SPECIMEN. mm.
Length of head,	22	16
Width " "	15	11
Length of body,	30	19
Metacarpal,	1½	1
Phalanges,	6	5
Third metacarpal,	32	19
Fourth "	25	16
Fifth "	25	14
Forearm,	21	12[1]
Thigh,	9	7
Tibia,	9	8
Foot,	15	9

The variations in size of the adult are so great that no advantages obtain from contrasting them with the proportions of the embryo.

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[1] This difference is remarkable.

In a young individual—naked, apparently recently born, yet without trace of umbilical cord, a minute tubercle was seen on the free border of the interfemoral membrane directly in the middle line. It did not appear to be connected with a tail.

Length of head, 15mm.; length of trunk, 30mm.

Lonchoglossa caudifera[1] ♂ (Plate V, Figures 4, 5.)

(The genera of Glossophagina are confessedly difficult, apart from the numbers and characters of the skull and teeth, and cannot with certainty be named. Since the skull was absent from the only adult specimen specimen at my command, I offer the above identification with some doubt. But the genera of Glossophagina are closely allied, and it is highly probable that the peculiarities of the specimen here described will stand for any of the group.)

The ellipse measured 20mm in length and 5mm in width. It was compressed from before backward. As in other examples from the typical Phyllostomidæ, this embryo showed one carpus placed higher than the other. In this instance the right is carried up to the level of the auricle, while the left is carried as far back as the occiput, thus the vertically placed forearm does not of necessity reach a point on the head nearer the vertebral column than the oblique one. The difference between the arrangement as seen in *Lonchoglossa* and that of *Mormops*, *Artibeus* and *Brachyphylla* lies in the extent of the deviation of the axis of the head from the vertical. The deviation in *Lonchoglossa* is greater than in any form examined (the longitudinal axis of the head passes through the right knee); not only is this the case but the head is rotated in such wise as to bring the left side well down on the front of the ellipse. It is readily seen how the oblique left forearm reaches a point farther back on the head than does the vertical right forearm. Both thumbs are extended, in this wise presenting a contrast with the acquired position of palmar flexion as seen in the adult. The right forearm and all the digits are adpressed, and the entire manus lies well on the side of the ellipse. The left manus is slightly abducted; the third digit passes across the front of the ellipse, and is straight except at the second interphalangeal joint where the third phalanx is abruptly flexed. Both legs are exposed on the same level and are not crossed. Considering the rudimentary character of the calcar in the adult, its size in the embryo is unusually large. Everywhere the skin exhibits a disposition to overlie the digits, so that the bones are not so distinctly seen as in other forms. The vertebral column is straight, not showing a trace of the twist which is conspicuous in *Molossus*.

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[1] Perhaps the degree of rotation of the head determines the position of the legs.

When the embryo is unfolded the left fourth digit is found to be abruptly flexed, but the fifth to be extended. On the right side the phalanges are flexed. The tongue projects for a distance nearly equaling the length of the face. The crown, back and sides of the neck covered with dark brown hair as in *Rhynchonycteris;* the rest of the animal is naked save the lower margin of the interfemoral membrane, which is fringed with hair.

The study of the displayed extremity, as in the position of flight, shows very ample provision for parachute-like support. The forearm is nearly horizontal (the angle between the arm and forearm open), the thumb on the outer border of the manus with the claws pointing upward. The membrane is without a trace of the straight lines of the interspace so characteristic of the adult Phyllostomines. A specimen with deciduous teeth yet in position accompanied the adult, and is of interest in showing the manner in which the proportions of the embryo have altered in a short time after birth. It can be safely inferred that this specimen was still a suckling, yet the proportions of the limbs have all assumed the relative values of the adult—the foot and thumb indeed having attained the exact size of maturity.

In the fœtus it is noticeable that the head is as large as the body; the forearm is nearly one-fourth the length of the part in the adult; the first metacarpal is one-third less than that of the adult; the difference between the lengths of the third digits is about three-fourths less than the adult; the fourth and fifth digits are of equal length; and the tibia is nearly three-fifths smaller. It is evident that the greatest rates of growth which take place are in the first metacarpal bone, in the third digit, and the tibia, while the least amount of growth takes place in the phalanges of the first digit and the foot.

	Embryo mm.	Adult.[1] mm.	A Specimen One-third Grown mm.
Length of head,	14	23	19
Width " "	8	15	10
Length of body,	14	35	30
" " forearm,	10	35	29
First digit { metacarpal,	1	3	3
First digit { phalanges,	4	5	5
Length of third finger,	20	73	50
" " fourth "	14	55	38
" " fifth "	14	50	35
" " femur,	5	14	10
" " tibia,	3	14	10
" " foot,	7	10	10

Glossophaga soricina ♂.—A single embryo of this species was obtained after the paper was ready for the press. The arms are disposed in a manner different from those of any other Phyllostomine bat so far examined. The specimen measured 15m. in length by 9m. in width. The right forearm was advanced so as to present the wrist in the face axis directly in front of the eye in a manner quite like that seen in *Pteropus*, as shown in Gervais' figure (p. 28.)

The digits, unlike those in this figure, were separated from each other as in *V. mystacinus* (p. 26.)

The left forearm was disposed as in other Phyllostomines, namely, was parallel to the trunk and presented the wrist at the side of the head. It laid directly beneath the down-drawn auricle. The lower limbs were flexed and disposed exactly as in *Lonchoglossa*.

The nose-leaf was well defined. The warts on the mentum as distinct as in the adult. The tip of the tongue protruded as in *Lonchoglossa*, but to less degree. It was not deflected. The tail was well outlined, and was in proportion to the interfemoral membrane as in the adult. Its tip extended to the level of the lower third of the tibia.

Desmodus rufus.—The embryo of this species furnished the model for the drawing (Plate VI, Figure 12) of the outstretched wing. The specimen was mutilated, being without a head, and the limbs had been allowed to fall away from the ellipse. The embryo is of interest on account of the relatively great length of the first metacarpal bone, the proportionate size as compared to the phalanges being almost that of the adult. The callosities, which form such conspicuous characters of this genus, are well developed. The second to fifth digits pass from the wrist at almost equal distances from each other, and the differences in their lengths are slight. The entire manus appears to be more compact than in other genera. The level of the third and fifth digits at the wrist is the same, while the fourth digit recedes. This character is repeated in the adult, but is much less conspicuous. The robust third metacarpal bone in the adult *Desmodus* stands out boldly from the palmar surface of the wing membrane, while it is not well seen on the dorsal surface; on the other hand, the fourth and fifth metacarpal bones are best seen from the surface last named. These characters are also noted in the embryo, but to a less marked degree. The short first phalanx of the second, third and fourth digits is noticeable in both embryo and adult.

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[1] From which specimen was taken.

The proportion of first phalanx of the first toe to the remaining toes is repeated, as is also the exceedingly short second phalanx to each of the other toes. The curious wart-like calcar is present. The greater variation in any part of the periphery is seen in the interfemoral membrane. Like the adult, the membrane is on a level with the skin of the loin and posterior surface of the thigh, instead of receiving pendant support from the junction of the thigh with the front of the pelvis, but it is pointed in the middle instead of extending evenly across the space between the thighs, and reaches the middle of the long leg by a narrow hem. The thigh is much shorter than the tibia, while in the adult they are of equal length.

		mm.
Length of trunk,		20
" " head,		14
" " forearm,		15
First digit	metacarpal,	1
	phalanges,	5
Second metacarpal,		9
Third to fifth metacarpals,		10
Leg (femur and tibia),		9
Foot,		12

The account of the embryos of the Phyllostomine bats would be incomplete without mention of an embryo of *Macrotus*. This specimen, unfortunately, was so far destroyed that description is impossible. It may here be noted, however, that the wrists were applied against the head on the same level, much as in *Mormops*, but differing from the positions seen in the foregoing specimens.

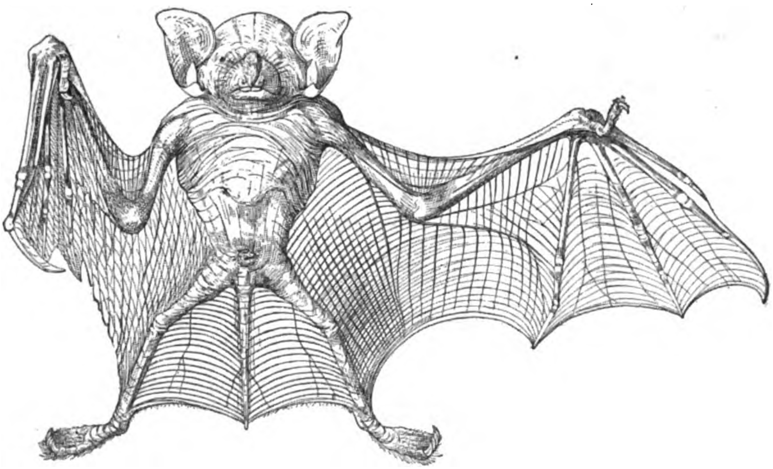

FIG. I.[1]—Embryo of *Natalus stramineus*, showing an internarial structure which suggests the form of a rudimentary nose-leaf. The adult is without sign of nose-leaf.

In the Proceedings of the United States National Museum, Vol. XV, I propose erecting *Natalus* to the position of a type of a new sub-family of Phyllostomine bats. I do this, notwithstanding the fact that *Natalus* is without nose-leaf in the adult form. The accompanying figure, taken from the paper just named, is here inserted in order to display an ovate elevation, which is placed with its long axis between the nostrils, and reaching from the lip-margin to a short distance above the edge of the muzzle. This is thought to be a rudiment of a nose-leaf. It is noted in the expanded wing membrane that a well-marked vertical line is seen in the third and fourth interdigital spaces, extending nearly over their entire lengths; also, that the second digit is closely approximated to the third, that the first metacarpal bone is flexed, and, at least, in the folded wing that the entire digit is brought well down in the palmar position. These characteristics, it is thought, ally *Natalus* to the Phyllostomines; it is of interest to note that all the features named are discernible in the embryo, and that two of them, *viz.*, the nose-leaf and the vertical interdigital line, are seen only in this early stage of development.

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[1] I am indebted to the authorities of the National Museum for the privilege of reproducing this figure.

Molossus rufus[1] ♂ (Plate VI, Figure 13).—Length of ellipse, 35mm.; width, 20mm. The head flexed so as to touch the left foot. The two forearms are parallel to the trunk and reach to the same point on the head, namely, the level of the occiput. Both wrists press firmly against the ear, and on the right side the auricle is visible in front and beneath the thumb, while on the left side the auricle is pressed down and is concealed by the wrist. The tail is inclined slightly to the left. Both thighs, as well as the left foot and calcar, are visible from in front. The right manus exhibits the digits closely adpressed, the first phalanx of the third digit is sharply adducted on the metacarpal; the corresponding bone of the fourth digit is dorsiflexed, while the fifth digit is straight and rigid throughout. The dispositions just named are not made out until the limb is slightly unfolded. The left manus with the first phalanx of the third finger sharply flexed on the metacarpal, the other parts as on the right side. The feet not overlapping, the right carried well up to the face as is the left foot, but is concealed by the manus. There is scarcely any twist to the inclination of the pelvis. The long tail is deflected to the left where it lies along the side of the neck.

When the limbs were unfolded the forearm is seen to be very oblique. The tubercle at the base of the fifth toe is distinct, that at the base of the first toe is absent.[2] The first and fifth toes are shorter than the others.

The deciduous teeth are in position. The auricle is quite the same as in the adult. The face in advance of the auricle is marked with glands, the orifice of which are conspicuous; they are arranged in series of seven on either side of the median line. The muzzle is as in the adult, except that the upper margin is spinose; the lower lip is not tumid. The eyelids are not closed but in contact. The interfemoral membrane as in the adult. The gular glands were well developed:

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[1] A single young stage of *Promops perotis* was seen occupying the *right cornu* of the uterus, the left remaining small as in the non-gravid condition.

[2] In the adult the tubercle is as a rule at the base of the first toe but often in line with the tibia. It is never at the base of the fifth toe.

		mm.
Length of head,		18
Width " "		12
Length of body,		23
First digit	metacarpal,	1
	phalanges,	6
Third digit,		22
Fourth "		19
Fifth "		14
Femur,		10
Tibia,		10
Foot,		10

Molossus abrasus (Plate VI, Figures 14–17).—This embryo represented an earlier stage than that of *Molossus rufus*. The shapes of the vertebræ can be discerned through the skin of the back. The length of ellipse 22mm., the width 18mm.

Three views are given of this specimen—the left side, the right side and the front. The head is not flexed to the extent seen in other specimens, and the forearms lie almost in the same positions as those assumed at rest[1]—as a rule in the entire order—namely, being brought well up parallel to the trunk, and having the distal end near the side of the neck and below the auricle. Yet the manus is semi-extended on the right side, the second, third and fourth fingers lying parallel with each other and contiguous. The fifth is not in contact with the fourth, and is drawn well backward (abducted; *i. e.*, drawn away from the other digits and toward the body). The triangular space defined between the fourth digit and the forearm is divided in the middle by this digit. The phalanges are variously disposed (Plate VI, Figure 16). Those of the third digit are abducted and laterally flexed; *i. e.*, turned toward the thumb; the first digit of the fourth finger is straight, while the second is flexed on the first; those of the fifth digit (Plate VI, Figure 15) are both straight.

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[1] The term "at rest" implies the position of the animal when not flying.

The left forearm and manus are closely adpressed. The thumb is in primitive position and on the surface of the ellipse; the remaining digits are concealed, except the fifth, which lies extended.

The vertebral column is remarkably twisted, the loin, sacral region and tail lying in a spiral (Plate VI, Figure 16) in front of the ellipse and the tail ending on the vertex of the face. The left auricle is pressed up against the head, the right downward. The eyes are as in the adult. When the ellipse is opened the right foot was found with its plantar surface directed toward the trunk, and the left, with dorsal surface directed outward, placed directly in front of it.

The exposed wing shows the very oblique position of the humerus and forearm, as shown as *M. rufus*, and which is so markedly different in the Phyllostomines and the equally oblique free margin of the wing membrane. The deflection of the terminal cartilages of the fourth and fifth digits away from each other is well shown.

		mm.
Length of ellipse,		22
Width " "		18
Length of head,		15
Width " "		9
Length of body,		20
Forearm,		10
First digit	metacarpal,	2
	phalanges,	3½
Third "		20
Fourth "		16
Fifth "		13
Tail,		17
Femur,		5
Tibia,		7
Foot,		8

Since the above was written I have come into possession of an embryo of *Molossus abrasus* of an earlier stage of any bat-embryo yet examined, with the exception of that of *Rhinolophus affinis*.

The specimen measured 11mm. long and 8mm. wide. Both mani were partially extended, and enwrapped the sharply flexed face. That of the right side exhibited the fifth finger, abducted much in the manner seen in the paddle of the manatee (Plate VIII, Figure 35).

No deciduous teeth were observed. Does this arise from the fact that the young "scurry," and are not bourne in among the short hair of the mother? The sac of *Chiromeles* would look to the same conclusion. Here the mother "scurrying" would prevent the young from being carried on the under surface of the trunk. This remark, indeed, would apply to all genera of the Molossidæ.

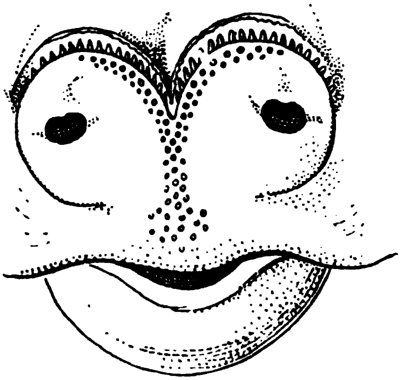

FIG. II.—Muzzle of embryo of *Molossus rufus* (×8), showing presence of marginal spine-like tubercles.

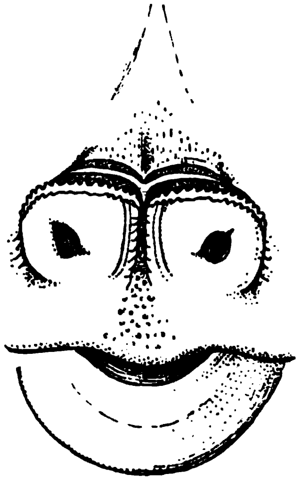

FIG. III.—Muzzle of embryo of *Molossus abrasus* (×8), showing presence of marginal spine-like tubercles. A median groove between the perinarial expansions are noted, as well as a skin-foliation above the muzzle.

Interesting observations were made on the muzzle of both *M. rufus* and *M. abrasus*. The upper border was furnished with spine-like tubercles arranged in serrated series, in a manner precisely like that seen in *Nyctinomus*. In *M. rufus* the tubercles were in a single series, and a number of minute papillæ arranged in part concentric therewith, and in part carried in the median line to the centre of the upper lip after the manner of the stiff hairs in the adult. In *M. abrasus* a second faintly defined row was seen just below the upper muzzle margin, while the two perinarial plates were separated by a groove above the muzzle, a rather well-marked fold of skin extended from a short median ridge as far as the outer margin of the muzzle.

It is to be regretted that material is not at hand by which comparisons can be made between the embryos of *Molossus* and *Nyctinomus*. I have not succeeded in obtaining embryos of the last-named genus; but the following facts are in our possession: *Molossus*, a smooth-nosed form, exhibits in the fœtus the marginal muzzle serrations of *Nyctinomus*.

Atalapha cinera (Plate VII, Figures 19–20.)—Four specimens were observed of this species.[1]

No. 1 (Figure 19). Length of the ellipse, 21mm; width of ellipse, 14mm. The specimen is remarkable from the fact that the upper end is not composed of the head only, but is, in great part, made up of the cervical vertebræ and the left scapula. This configuration is the result of the degree to which the head is flexed, the muzzle ending at the lower third of the ellipse. Hence the head is brought down to a vertical position, and on the front. The ellipse is much compressed at the sides, thus narrowing the front and back surfaces; the vertebral column is twisted to the left, and the tail is brought up forward to rest on the face in a manner exactly similar to that observed in *Molossus abrasus*. The lower end of the ellipse is not the region of the pelvis but of the left tibia. By reason of the tilt in the region of the sacrum, the pelvis lies on the right side instead of beneath, and the lines of the thighs (which retain their invariable position at right angles to the long axis of the innominates) trend obliquely upward and forward, so that the right foot lies against the head. It is not easy to account for this exceptional relations of the parts. If we assume that the extent to which the bending of the head had taken place had forced the vertebral column to one side, and that the lateral compression of the embryo had subsequently forced the thigh to assume an oblique position, it is difficult to explain the shape of the ellipse in *Molossus abrasus* where the parts are arranged much in the same manner as in *Atalapha cinera*, with the exception of a less degree of flexion of the head, left shoulder, and foot.

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[1] One of these was received through Mr. G. S. Miller, Jr., Cambridge, Massachusetts, who has, on many occasions, given me valued assistance.

No. 2 (Figure 20). Length, 16mm.; width, 12mm. The ellipse in this specimen is less intricately folded than is No. 1. The head is bent down to a less degree, the vertical column is curved forward with a slight twist, so that the pelvis lies nearly transverse at the lower end of the ellipse, and the thighs appear on the anterior surface. The longitudinal axis of the head is inclined but slightly away from the longitudinal axis of the ellipse. The line of the tail, if produced slightly, would reach the face. The forearms end at points opposite the sides of the neck. The interval between the fourth and fifth digits is decided, while the second, third and fourth are close together. The legs are sharply flexed on the thighs and the feet are superimposed, the right being on the surface.

The limbs being unfolded the following appearances are seen (Figure 21): The interval between the second and third digits almost nil—closely resembling in this respect the adult forms of *Molossidæ*. The third and fourth interdigital spaces subequal. The third digit is in the same line with that of the forearm. In this respect the species is peculiar. The thumb is turned upward thus resembling the other Vespertilionines and *Molossus*.[1] The entire membrane is narrow. Both auricles are provided with black margins as in the adult. The left ear is pressed down; the right ear lies against the head; the fifth toe on the right side is abducted. Head, 7mm.; foot, 6m.; thumb, 5m.

(3). The specimen (♀) sent by Mr. Miller was already unfolded from its membranes. It will serve for the comments to be made on the study of the wing membrane, etc. (p. 34).

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[1] While the inclination of the thumb thus suggests the affinities recognized by me in the relationships of these forms, the thumb is turned up in *Artibeus* and *Lonchoglossa*, but down in *Brachyphylla* and *Desmodus*.

Both upper extremities are sharply flexed, the membranes of the interdigital spaces forming folds in front and tending to conceal the digits. The limbs are symmetrically arranged and the manus on each side and evenly disposed against the front of the chest. In like manner the feet are brought up with their plantar surfaces against the abdomen, without distortion or overlapping.

The contrast between the parts in this embryo and that of the specimen No. 1 is very great. The general color of the specimen is fawn; the thighs and legs are much darker than the prevailing shade, while the thumbs, feet and the margin of the auricle are black. The tail and interfemoral membrane are as in adult; the tip of the tail is barely exsert.

		mm.
Length of head,		12
Width " "		8
Length of body,		16
" " forearm,		10½
First digit	metacarpal,	2
	phalanges,	3
Third digit,		14
Fourth "		12
Fifth "		11
Thigh,		5
Leg,		6
Foot,		8

The auricle with the external basal lobe is continued distinctly to the angle of the mouth. The external basal lobe is scarcely at all developed. The basal ridge on which the tragus lies is enormous, and forms a welt-like mass on the side of the face. The shape of the tragus is not determinate, but is certainly not characteristic of the adult.

(4) (5281 National Museum). In this specimen the ellipse measured 16mm. long and 10mm. wide. The arrangement of the limb was quite the same as in specimen No. 2 for the right side. But on the left the forearm and closely adpressed digits were brought directly in front of the deeply flexed head. The auricle was bordered with black as in the adult.

Atalapha noveboracensis. (Plate VII, Figure 18.)

Three embryos were obtained of this species. Each was 11mm. long and 6½mm. wide. They were all in poor condition; the occipital elements are not united. The specimens exhibit great degrees of flexion of head. The forearms are closely flexed, and the digits were adpressed. The left wrist is sharply elevated.

Two of the specimens are twins. The ellipse by mutual compression are much distorted. The parts in the superimposed ellipse are much the same as in No. 1, but the right forearm is thrown in front of the head and slightly crossed to the left. In the lower fœtus the head is placed almost transversely; the forearms are far apart and the left manus is brought over the snout. The right foot is turned up alongside the outer side of the leg.[1]

The phalanges of the manus were all adducted in a cluster on the metacarpals, so that they lay directed toward the body parallel to the forearm.

	mm.
Length of ellipse,	13
Width " "	8
Length of head,	8
" " forearm,	5
" " foot,	6

The accessory cartilage on the somad side of the terminal cartilage of the fifth digit is distinctly visible.

Adelonycteris fusca. (Plate VII, Figures 22–24.) Two specimens of this common species were available.

No. 1. Ellipse broad, much flattened from before backward. Length, 21mm.; width, 17mm. The head is sharply flexed, deflected slightly to the left, and is rotated on its longitudinal axis, so that the evenly placed forearms do not come in contact with the head at the same places, the right wrist lying back of the ear, while the left wrist is under it. Still the right wrist is actually a little higher than the left.

The manus on both sides is almost entirely concealed by the large fold of wing membrane which lies between the fifth digit and the body. Both thumbs are in primitive position.[2]

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[1] In a single individual of *Atalapha frantzii*, recently born, two symmetrical white subdermal macula were noted in the skin of the abdomen.

[2] It has been already stated that the words "primitive position" imply the retention of the thumb on the plane with that of the other digits, and has no reference to the upward or downward position of the claw.

The vertebral column is markedly deflected to the left from the loin downward, carrying the pelvis and thighs in the same direction; the right leg inclines also to the left and reaches a point at ankle at the median line of the ellipse surface—thence the foot is turned abruptly to the right and is pressed up parallel to the leg; the exposed calcar is thus bent sharply on itself.

The left leg and foot lie behind the right, well up under the right side of neck. The tail is flexed in the same direction, (thus deflected to the right abruptly away from the left of the vertebral column), its tip lying beneath the right auricle concealed by the right foot.

The membrane being unfolded shows the head to be 15mm. long and 11mm. wide. The second and third digits lie over the fourth, which is borne more palmad than the other, thus concealing the fourth digit when the wing is unextended. The skin of the fourth digital interspace in folded inward. The parts are similarly arranged on the left side.

The first toe is shorter than the others and there are two plantar tubercles, one at the base of the first, and one at the base of the fifth toe. The exsert portion equals one-seventh the length of entire tail. Both auricles are pressed down. The region of the external basal lobe indeterminate. The chin plate markedly triangular and surrounded by obscurely defined warts.

No. 2. This specimen is less mature than the preceding. It measured but 14mm. long, 6½mm. wide. The left forearm crosses the trunk below the sharply flexed (to the left deflected) head and overlies the right forearm which, with the manus, is adapted to the trunk quite as in No. 1, but does not reach as high as the auricle; the right foot is exposed. The tail on the front of the ellipse. The thumbs are in the primitive position. All the digits are closely adapted, *i. e.*, there is no interval between the fifth and the fourth, nor is fourth drawn palmad. Tail as in *Molossus*, the distal half exserted.

No. 1.	mm.	Specimen of Newly Born. Umbilical Cord not Absorbed
Length of head,	15	12
Width " "	7	8
Length of body,	16	16
Forearm,	15	14
First digit metacarpal,	2	1½
phalanges,	5	3
Third digit,	16	17
Fourth "	15	13
Fifth "	15	12
Thigh,	7	6
Leg,	8	7
Foot,	8	6
Tail,	12½	13

In a number of hairless specimens of this species—evidently young at the breast—the wart on the gular region and on the face behind the angle of the mouth were distinctly seen. The outer basal part of the auricle was indeterminate and ended below the level of the mouth.

Vesperugo carolinensis (Plate VII, Figures 25, 26).—The plan of arrangement in this species is almost identical with that of *Adelonycteris* and *Vespertilio.* The fifth digit is drawn in abduction, while the remaining digits are close together and are in adduction. Prof. Burt G. Wilder[1] has paid special attention to this form under the identification of *Vespertilio subulatus.* I have been permitted, through the courtesy of Prof. Wilder, to examine the material on which his paper was based, and have had figured (Plate VII, Figure 25) the uterus containing two embryos, as well as the embryos themselves, showing the results of pressure against each other.

Vespertilio albescens (Plate VII, Figure 27–29; Plate VIII, Figures 30, 31, 32).—Two embryos were examined of this species. The general resemblance of these to *Adelonycteris fuscus* is marked. The same disposition to symmetrical position of thighs and the low position of the wrist is seen in both species.

No. 1 (No. 12,450, Arizona.—National Museum).

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[1] "Bats and their Young"—*Popular Science Monthly*, 1876, p. 1.

Length of ellipse, 18mm.; width, 11mm. Head at right angles to the body. Both wrists are on the left side of the neck, owing to the fact of the right forearm being carried across to the left side of the body. The feet are not crossed, but both are exposed on the left side, the right being above the left. The left foot as well as the right arm thrown well over to the left, lies proximally to the right foot, and partially concealed by the wing membrane.

The parts being unfolded, show the manus of both sides closely pressed against the forearm. The wing membrane from the body to the fifth digit folded outward, but that of the fourth interdigital space folded inward. The thumb is in the primitive position. The head is 11mm. long and 8mm. wide. Both auricles are turned forward. The external basal ridge of the auricle is large and firm, the anterior half forming the external basal lobe.

No. 2 (No. 15,146, Mexico.—National Museum).

Length, 10mm.; width, 7mm. Quite as in *A. fusca*, even as to left wrist lying under the left ear and the left foot being exposed, instead of the right. The left third digit is flexed well toward the body not flexed on self, as in *A. fusca;* the left fourth digit is flexed toward body. All the digits appear to be relatively longer than in *A. fusca;* the tail is carried up to the left. Both auricles are pressed downward and forward; the outer border of the tragus is smooth; the eyes are open; the hair on the terminal cartilage of the fourth digit is present.

No. 3.

Length, 18mm.; width, 11mm. Wrists at sides of head symmetrical. Both upper extremities exposed; the right is more displayed than the left. The right foot lies on the surface of the ellipse; the left foot is turned down and the toes lie against the right thigh. This auricle is distinctly more pigmented than the rest of the body. No hair is found on the terminal cartilage of the fourth digit. Ends of digits manus crumpled up without system. Head, 14mm.; foot, 8mm.; thumb, 5mm.

No. 4 (No. 29,834, California.—U. S. Agr. Dep't).

Length, 13mm.; width, 9mm. This specimen is remarkable for the fact that the forearms are crossed in front of the chest and have no relation to the free end head, which, when removed from the membrane, assumed a position of a right angle to the ellipse. The left foot lies directly on the outer surface of the ellipse and clasps the horizontally placed left forearm.

In Plate VIII, Figure 31, a number of warts are displayed on the under surface of the head, between the angles of the jaw and the chin. They are very conspicuous, and it is strange that, in the study of the adult, attention has not been called to them. But when the skin is covered with hair they are nearly concealed, and even when sought for with the aid of a lens they are made out with difficulty. An adult specimen of *Vespertilio emarginatus* from the south of Europe exhibited the warts as seen in the adult to greater advantage than any specimen of a North American species yet examined. I have not detected a similar disposition of warts either in *Vesperugo* or *Adelonycteris.*

Vespertilio nigricans. Length, 12mm.; width, 7mm. The head is inclined mostly to the right; the right arm lies against the neck; the forearm and manus are not seen, while the left forearm is vertical and the wrist lies on the head at the occiput. The thumb is extended and the tail passes the crown. Both feet are exposed on the point of the ellipse, the right being the lower. The tail is folded up in front to the left. The membrane being unfolded shows the head lying in angle between the arm and the forearm, and the wrist pushed over to the left, where it lies against the arm. The right thumb is pressed well in palmad. The tail is not exsert for the membrane, thus presenting a marked contrast to *A. fusca.*

Vespertilio nitidus. A single embryo was obtained of this species. Length, 10mm.; width, 8mm.; closely resembles the foregoing. The fifth finger is strongly adducted.

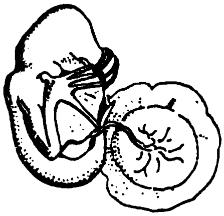

FIG. IV.—Embryo of *Vespertilio mystacinus* (after Gervais), showing the separation of digits, and marked abduction of the fifth digit.

The only figure of an embryo of the genus *Vespertilio* known to me is that of the European *V. mystacinus*. It is described by P. Gervais (Journal de Zoölogie I, 1872. Plate XXII, Figure 1). A copy (Figure IV.) appears on preceding page. The attitude of the manus is quite distinct from that assumed in the North American species. The digits are displayed and the membrane therefore without folds.

Rhynchonycteris naso. ♂. (Plate VIII, Figures 33 and 34.) The single embryo of this interesting form measured 17mm. in length, and 10 mm. in width. The head is sharply flexed but exposed completely at the front of the ellipse. The right forearm is at the side of the ellipse, the manus with digits on one level and all adpressed. The thumb is extended over the upper part of the occiput; all the digits are straight, excepting the first phalanx of the third digit, which is abducted. The left forearm is adpressed, and lay obliquely downward and inward. The manus (excepting the thumb, which is extended at the back of the hairy occiput) is completely closed, and the metacarpal twisted so as to lay under the forearm, while the ends of the digits are as the front of the ellipse. This arrangement is maintained in the adult. The legs were brought up evenly and symmetrical in front, but concealed by the upper extremities.

When the limbs are unfolded the number of the elements in the feet are seen to be the same as in the adult. The tail is slightly longer—the thumbs, feet and calcars are enormous. The auricle is pointed, the internal margin advanced to the position of the eye, the external margin convex and reaches the angle of the small mouth. It carries a well-developed external basal lobe. The tragus is small and rounded. The markings on the wing membrane are the same as in the adult. The proportions are about as in other embryos. The great size of the thumb and foot are notable. The eye is large and apparently without lids. With the exception of the early stage of *Rhinolophus*, no other specimen was so distinguished.

	mm.
Length of trunk,	13
" " head,	9
" " forearm,	10
" " third digit,	12
" " leg,	4
" " foot,	5

The foot is relatively small. The proportions of calcar, interfemoral membrane and tail as in the adult.

Figure V. illustrates the appearance of the ventral aspect of the neck of *Rhynchonycteris*. The entire region was occupied by a convex mass covered with skin. When this was opened, it was found to contain a quantity of loosely granular fat.

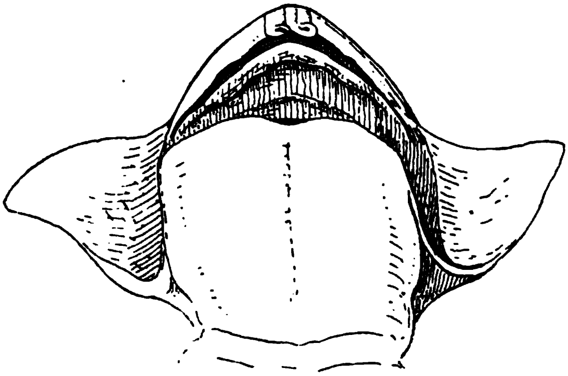

FIG. V.—The under surface of head, with venter of neck, of *Rhynchonycteris naso*, showing the large, fat mass.

The only figure of the embryo of a fox-bat known to me is that figured by P. Gervais (Academy des Sc. et Lettres de Montpellier, 1852, p. 33), and reproduced in an article by the same author (Journ. de Zoölogie, I, 1872). The position of the wrist in advance of the face is repeated in *Glossophaga* (q. v.). In other respects the figure is not remarkable, and, indeed, is imperfect, for no trace of inferior extremities is discernible. (See Fig. VII.)

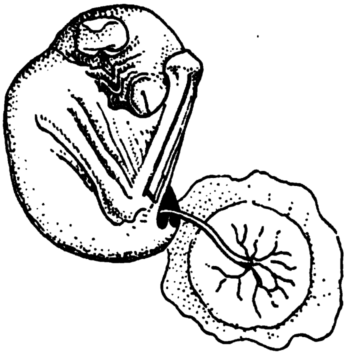

FIG. VII.—Embryo of fox-bat, *Cynopterus marginatus*. (After Gervais)

The young of the fox-bat suspends itself to the woolly fur of the thigh of the mother. Nowhere else in the adult is the hair so distinct in character as on the rump and the ventral aspect of the thigh. It is woolly, abundant, and ordinarily of a darker shade of color than the rest of the trunk. I assume that this character of hair is a special adaptation to enable the young to secure a firm hold with the long, sharply-curved claws. (See Fig. VIII.)

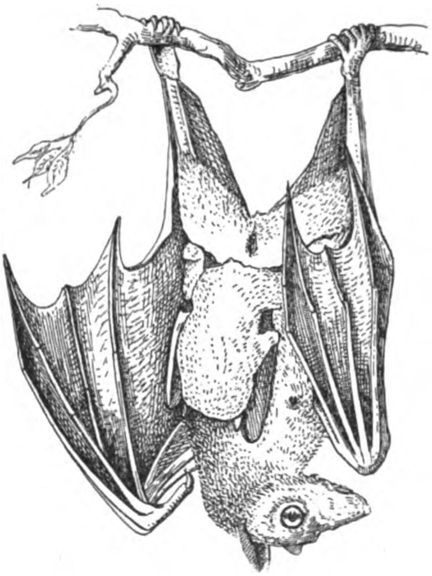

FIG. VIII.—Figure of fox-bat (*Cynonycteris collaris*) with young. It is noted that the young is suspended in much the same fashion as the adult. The hind feet hold to the woolly hair of the rump and thighs of the mother. Copied from "The Animals Living in the Gardens of the Zoölogical Society," London, 1879, page 42.

The position formerly assigned to *Galeopithecus* as a transitional form between the ordinary type of terrestrial mammal and the bat, warrants the introduction at this place of the following note and comment. P. Gervais (Journ. de Zoölogie, I, 1872, Plate XXII, Figures 2, 4, 6), has figured the embryo of *Galeopithecus*. The most striking contrasts presented between this form and that of any of the examples which illustrate this memoir, appear in the manner of flexion of the head (the entire series of the cervical vertebræ being bent forward with the head), and in the rigidly extended, laterally disposed extremities. (See Figure VI.)

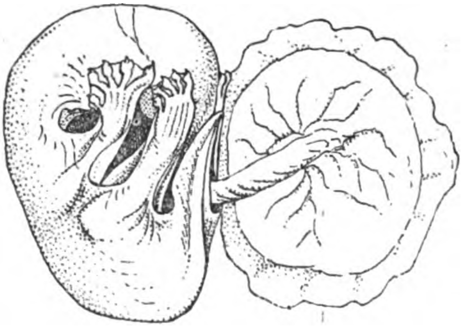

FIG. VI —Embryo of flying lemur, *Galeopithecus*. (After Gervais)

LITERATURE.

Little has been written on the embryos of bats. In addition to the short communications of Gervais, noted above, I can recall but one essay, already cited, namely, that of Prof. B. G. Wilder. ("Bats and their Young." Popular Science Monthly, 1876, III, 650) In this admirable paper the early stages of *Vesperugo carolinensis* (named in the paper *Vespertilio subulatus*) are described and figured.

GENERAL CONSIDERATIONS.

In reviewing the subject I have arranged my impressions under the following heads:

(1.) Observations on the Relations to each other of the several Parts of each Embryo.

(2.) Observations on the Expanded Wing.

(3.) Taxonomical Considerations.

(1.) As a rule the disposition for the digits to be grouped by the lines established for them in the carpus obtains. Thus the fourth and fifth digits tend to be abducted and separated from one another, while the second and third tend to be adducted and kept together. The fourth and fifth metacarpal bones agree in carpal relations, since they both articulate with the unciform bone; they are also closely related in their muscles, since they both are moved by the abducting manal group, *viz.*, the *flexor carpi ulnaris* and the *extensor carpi ulnaris*. The second and third digits, on the other hand, are articulated each with its own carpal element, and are acted upon by separate extensors (*viz.*, the *extensor carpi radialis brevior* and *extensor carpi radialis longior*).

It will be seen that the disposition in the Phyllostomine forms (*viz.*, *Mormops*, *Artibeus*, *Brachyphylla* and *Lonchoglossa*) for the phalanges of the digits of one of the anterior extremities (the one which is placed the highest on the side of the head), is the same throughout. The phalanges are not deflected, as a rule, from the lines of the metacarpal bones, and even in the exceptions they are but slightly deflected (see Figure 2, left side). The vertebral column at the loin is not deviated from a straight line ; nor is the pelvis tilted.

Thus the general shape of the manus is best accounted for by the results of muscular action. Unlike the problem in terrestrial forms—but quite like the one recognized to be present among the aquatic—the weight of the body is here no longer a contributory cause to the shape and behavior of the limb. The "wing," as in Chiroptera, and the "flipper," as in Sirenia, and, in less degree, in Cetacea, have much in common. The disposition in the embryo of a dugong 35cm. long (Figure 35, Plate VIII) for the fifth finger to be abducted is noteworthy. I think that the degree of abduction when marked is also associated with the fourth finger, being carried toward the ulnar (posterior, hypothenar) side of the flipper. The third finger never so moves but is disposed toward the radial (anterior, thenar) side.

But the material at hand for purposes of comparison is inadequate for any broad deduction to be made. It is seen that in two closely allied species of *Molossus*, the arrangement of the parts are in great degree contrasted. In *Vespertilio*, individuals of *V. albescens* differ as to degree of flexion of the head, and the positions of the wrists. Nevertheless the manner of dis posal of the limbs and the dermal expanse is not without its significance. In a general way it may be said that bats that are united by family or sub family tests are also to be distinguished by the manner of folding the limbs in *utero*.

In this connection the reader should note, as already mentioned, the tendency for the third finger of Phyllostomine bats to be straight or inclined forward, and for, at least, one wrist and thumb to lie on the side of the head; for the wing membrane under the forearm (mesopatagium) to overlie and conceal the manus in most Vespertilionines; and for the same parts to be disclosed in *Atalapha.*

The following data may be reviewed in this connection: In *Brachyphylla* the loin is seen in the median line of the embryo, and one wrist is placed much higher than its fellow. The head is well flexed; scarcely any deviation is evident of the undisplayed metacarpals.

In *Molossus* (*M. rufus*, *M. abrasus*) the wrists are nearly on the same level, and lie on that side of the head which is flexed in the least degree. The phalanges are variously deflected and are bent toward the body or are deeply flexed. The face is not concealed at any part by the wing membrane, or by the feet.

In *Atalapha* (*A. cinera* and *A. noveboracensis*) the wrists are also disposed to be on nearly the same level, and the metacarpals are widely displayed.

In *Adelonycteris* and *Vespertilio* the parts are quite similar to one another. They resemble, in marked degree, the species of *Molossus.* The membrane answering to the form beneath the forearm (mesopatagium) projects in a loose fold which tends to conceal the manus.

It is a remarkable fact that the widest (*i. e.*, the parachute-like) membrane should exhibit the least disposition to fold while the relatively narrowed wing of *Vespertilio*, *Adelonycteris* and the Molossidæ should be much folded.

In *Rhynchonycteris naso* the ellipse is apparently not distinctive in the arrangement of the limbs, but the disposition of the thumbs (the right thumb over the vertex and the left behind the occiput), is not seen in any other form. In the growth of short hair over the crown and back of neck the fœtus recalls *Lonchoglossa.*

The growth of an embryo in ovum may be said always to include the following conditions: First, when the fœtus has a length greater than that of the investing structures, the trunk is flexed at the ends. It may be justly assumed that the flexion is due to the necessity of packing the fœtus in a chamber smaller than itself. But not only are the ends of the fœtal ellipse thus flexed, but a disposition exists for the head to be deflected and partially rotated upon itself. It is again assumed that such position is the result of increase of pressure over and above that first named.

The size of the fœtus as compared to that of the body of the mother is enormous. One can but wonder how the small diameter of the pelvis permits so large a mass to descend! It is true that in the female of most forms, the symphysis pubis is not closed, and the inferior strait not limited by a rigid coccyx and by ligament. Yet in the Lobostomidæ and Rhinolophidæ the symphysis is rigid and complete in both sexes. The embryo of *Mormops* is much smaller than is proportionally the case with other bats figured, and it is probably true that a taxonomic relation is to be here acknowledged between the size of the embryo and the shape and size of the pelvis.

The proportions of the head, feet and thumb are noted. It is a remarkable fact how large are these structures when considered relatively to other parts of the limbs and to that of the trunk. In bats to degrees, perhaps greater than is seen elsewhere in the Mammalia, the feet and thumbs are longer in proportion to the size of the head, trunk and the bones of the main divisions of the limbs. This arrangement is probably associated with the manner of the young being carried by the mother. The disposition for the thumbs and feet to be occasionally in the adult of the proportions of the immature I have discussed elsewhere (Monograph N. A. Bats, Bull. No. 43, Nat. Mus. 1893, p. 73.) The proportions of the interfemoral membrane, as a rule, are quite different from those of the adult. It may be said that it is more ample than in the adult, in tailless or short-tailed and restricted in the long-tailed forms.

(2) The degree of extension naturally possible (I mean a natural possibility as opposed to the enforced possibility of the hands of the operator pulling on weakly checked mechanisms) to the second metacarpal bone on the forearm is also a guide to directions and amounts of strain on the wing margin. In

Atalapha the second metacarpal can easily be brought in axial line with the forearm; in *Molossus* to a slightly less extent; while in Phyllostomines to an extent still less. (*Vide infra.*)

In the adult the degree of obliquity of the axis of the forearm to that of the arm is also in great measure under the control of the observer. It is far different in the fœtus, where it is evident no traction can be used. The angle formed by the forearm and arm is distinctive in the Phyllostomines as opposed to the Molossines and Vespertilionines.

Fixing the proportions are difficult if not impossible, since these may vary in the history of each embryo, and it is manifestly uncertain what relation exists between the size of an embryo and the degrees of development attained in all parts of the limbs. The size of the thumb is of the same significance as in the adult. The first metacarpal bone is large in all forms.

(3) Palmar flexion of thumb in Phyllostomines is an acquired position (it is absent in *Desmodus*, and scarcely seen in *Phyllostoma*); for the primitive position is that of the thumb lying on the same plane with the other members of the manus. Hence the Chiroptera exhibit another of those characters of the Primates, which, like the pectoral position of the mammæ, the discoidal placenta, the lemur-like aspect of the head of Pteropines (to which we may now add the enfolded embryo), and the pendulous penis, explains, if it does not excuse, the high position given the Chiroptera by Linneus.

The shapes of the unfolded wing as studied in the figures are different in the four families represented.

The Phyllostomidæ exhibit wings with a low, open angle between the arm and forearm;[1] a wide membrane between the fifth digit and the body and leg; and the angle forward between the axis of the body and the free margin of the space between the third and fourth finger being never more than 20°.

The Molossidæ, in which the angle between the forearm and arm is more acute than in Phyllostomidæ; the membrane between the fifth digit, the body and leg narrow; and the angle between the axis of the body and the fifth digit never less than 40°.

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[1] The apparent exception to this statement in *Mormops* (Plate V, Figure 3) is due to the condition of the specimen not permitting traction to be made on the forearm.

The Vespertilionidæ, in which the angle of the forearm and arm is as in Molossidæ; and the angle between the axis of the body and the free margin of the membrane between the third and fourth digit between 60° and 90°.

In the Emballonuridæ, illustrated by the genus *Rhynchonycteris*, the features named recall those of the Phyllostomidæ, and are certainly not all like those of the Molossidæ with which group systematists have hitherto placed them.

The appearances above enumerated are not of the same significance. The width of the wing membrane and the relative width of the first digital interspace are persistent features, that is to say, they characterize both the young and adult stages. The degree of angulation of the free margin of the third digital interspace is a character of the young only, and is probably due to differences in the rates of growth of the digits, especially of the metacarpal bones.

There is no disposition for any embryo, so far as observed, to exhibit the remarkable arrangement of the skin of the back seen in *Pteronotus*, or in the formation of axillary sacs carried well up beneath the skin of the back as in *Chiromeles*.

Among other negative features may be mentioned the shapes of the deciduous teeth. I examined the deciduous teeth of *Molossus*, to determine if possible a correlation between the shape and size of these teeth, and the manner by which the young might be carried by the female. In forms which, when at rest, bring the ventral surface of the trunk well down on the plane on which the animal lies cannot, one would suppose, carry the young in the manner seen in the picture of *Cynonycteris collaris*. But the teeth are nearly of the same character in *Molossus* as in other bats, nor are any special provisions visible by which the young can hold to the short hair of the mother.

The fact that in all adults of families other than the Vespertilionidæ and Molossidæ, the proximal ends of the second to fifth digits, are sharply defined, while in the superfamily just named, the ends are obscured or entirely concealed, lead me to examine critically the embryos in this regard; but the appearances, on the whole, are inconspicuous and not important.

The position of the pisiform bone in Vespertilionidæ and Molossidæ, as a splint strengthening the fifth metacarpal, correlates readily with the data derived from the embryo which tend to unite these groups in a superfamily, and to separate the other families in which the pisiform is either very small, although in normal position, is carried well to the centre of the carpus, or, while in that position, is ossified with the os magnum.

In this connection it is of interest to note how the quinitidigitate manus in aquatic forms of life exhibit a similar abduction of the fourth and fifth digits. In illustration see the paddle of an embryo of the dugong. (Plate VIII, Figure 35.)

The scale by which we measure natural phenomena is often a small one. The constancy of minute structures indicates the methods of movement of a bat's wing quite as well as larger structures. Among such details may be named the terminal cartilages of the phalanges. If these lie in lines of the phalanges there is equable strain between the phalanges themselves or between the last phalanx and the wing base, as in Pteropidæ, Rhinolophidæ and Emballonuridæ. But if they are deflected from the lines of the phalanges they indicate inequable strain. In *Adelonycteris fusca* (Plate VII, Figure 24), for example, the fifth digit indicates strain on the wing margin toward the body, the cartilages of the third and fourth digits are directed toward each other, and hence show a strain of quite a different kind from the foregoing. In Phyllostomines the strain is evenly distributed, and trends both entad and ectad, while the terminal cartilage of the fourth digit is either spatulate or bicornuate.

In studying the young stages of development of animals it is always interesting to observe the characters which are transient and those which persist. The transient characters often throw light upon true relationships; for of two genera in a natural group one may have anatomical features in common at one stage of existence, yet be sharply delineated at another stage by the dissimilarity in these same features.

Thus the genera *Nyctinomus* and *Molossus* are separated among other characters by *Nyctinomus*, having the upper border of the muzzle furnished with spines, while in *Molossus* the spines are absent. Now I have found in the embryos of both *Molossus rufus* and *Molossus abrasus* these spines not only present, but arranged in two rows, exactly defining the upper borders and extending thence slightly toward the middle line, and the other lying concentric to this row, and not so well developed. Above the muzzle two obscure transverse plications are seen, which are peculiar to the embryo.

The fact that two genera so closely allied as are *Nyctinomus* and *Molossus* should be separated by characters which cannot be interpreted unless we study the embryos, suggest that these forms are more than ordinarily plastic.

In marked contrast to the transient characters of the muzzle in *Molossus* and *Natalus* (See Figure 1, p. 14) are those of the Phyllostomidæ. As illustrated in the genera *Mormops*, *Artibeus*, *Brachyphylla* and *Lonchoglossa*, the identification could be made almost as readily as in the adult. The snout of *Rhynchonycteris*, which is prolonged and proboscis-like, is actually exaggerated in the embryo.

Differences in the positions of parts may vary in adults when they are uniformly present in the embryos. In adult forms of the Vespertilionidæ and the Molossidæ the thighs are borne at right angles to the side of the trunk, and the leg at right angles to the thigh. In all other families of Chiroptera they tend to be borne at varying angles to the back of the trunk, and the leg to be extended in flight in the same line with that of the thigh or at an acute angle with it Absence of material for study in the Pteropidæ and Rhinolophidæ prevent further exact statements. But this fact is of value, that in all embryos examined, the position tends to be that of the first group. I infer from this that the disposition for the thigh to pass back of the line of the side of the trunk, is an acquired one, and that it is a more specialized character than that in which the thigh remains on the same plane with that of the side of the trunk. In the Vampyri (especially in *Macrotus*) and in *Rhinolophus*, backward traction of the thigh is carried to its highest degree.

That the first digit is relatively larger in the embryo than in the adult might be expected, when the fact is known that the digits from the second to the fifth (the wing digits *par excellence*) are relatively smaller. The thumb and foot enable the young animal to cling to the mother's fur, and the provision for this function is arranged in *utero*.

Desmodus and *Phyllonycteris* agree in the permanent retention of the large thumb. These genera are widely separated in the family Phyllostomidæ. But they agree in one respect, namely, they live on thick fluids—*Desmodus* on blood, *Phyllonycteris* on the pulp of grape-like berries.

As a result of the study of the embryos it can be said that bats exhibit differences between the fœtal and adult forms of a kind and degree greater than those noted elsewhere in the Mammalia, and that these differences indicate that, notwithstanding the high degree of specialization attained by the Chiroptera, the contrasts between the embryonic and adult forms are numerous, and that they may be accepted as evidences of the relatively low grade of the entire order.

EXPLANATION OF PLATE V.

Figure 1. Embryo of *Rhinolophus affinis.*
The characters of extremities not differentiated.
x. Anterior extremity.
y. Posterior extremity.
u. Tail.
Figure 2. Embryo of *Mormops blainvillii.*
Proximal ends of the II-V metacarpals unossified.
I, II, III, IV. Digits of left manus.
f. Left foot.
t. Right femur.
a. Right auricle.
Figure 3. The same with the right wing unfolded.
The third and fifth digits are nearly of the same length.
Figure 4. Embryo of *Lonchoglossa caudifera.*
a. s. Left auricle.
a. d. Right auricle.
I, II, III, IV. Digits.
c. s. Left auricle.
c. d. Right auricle.
g. Tongue.
u. Umbilical cord.

Figure 5. Same, with right wing unfolded.
I, II, III, IV. Digits.
1, ph., 2, ph., 3 ph., phalanges.
t. c. Terminal cartilage.

Figure 6. Head of *Brachyphylla cavernarum.*
Showing on right side II, III, flexor on occiput, but V extended and parallel to axis of face.

Figure 7. Embryo of *Artibeus perspicillatus.*
I, II, III, IV, V. Digits.
u. Umbilical cord.
a. s. Left auricle.
f. r. Forearm.
s. c. Left leg.

Figure 8. Extremities of right side of same unfolded.
The parts are named as in Figure 3.

Figure 9. Embryo of *Brachyphylla cavernarum.*
I, II, III, IV, V. Digits.
a. d. Right auricle.
u. Umbilical cord.

Figure 10. The same seen foreshortened from lower end of the ellipse

EXPLANATION OF PLATE VI.

Figure 11. The right extremities of *Brachyphylla cavernarum* unfolded.
Parts named as in Plate V, Figure 3.

Figure 12. The same of *Desmodus rufus.*
Parts named as in same.

Figure 13. Embryo of *Molossus rufus.*
a. k. Ankle of left foot.

Figure 14. Embryo of *Molossus abrasus* drawn from left side.
I, V. Digits.
o. Mouth cleft.
a. s. Left auricle.
c. Wrist.
v. c. Vertebral column.
s. Sacrum.
u. Umbilical cord.
t. Tail.

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Figure 15. Same drawn from right side.
II, III, IV, V. Digits.
a. d. Right auricle.
t. Tail.
m. p. j. Metacarpo-phalangeal joint.
d. f. r. Right forearm.
Figure 16. Same drawn from in front.
x. Space between left auricle (a. s.) and the cheek.
Figure 17. The same right wing and leg unfolded.
Parts named the same as in Plate V, Figure 3.

EXPLANATION OF PLATE VII.

Figure 18. Embryo of *Atalapha noveboracensis.*
I, II, IV, V. Digits.
u. Umbilical cord.
Figure 19. (No. 1.) Embryo of *Atalapha cinerea.*
III, IV, V. Digits.
d. a. Right auricle.
u. Umbilical cord.
d. p. Right foot.
d. g. Right knee.
t. Tail.
s. g. Left knee.
Figure 20. (No. 2). A second individual of the same species.
I, II, III, IV, V. Digits.
d. m. Right manus.
d. p. Right foot.
u. Umbilical cord.
t. Tail.
a. s. Right auricle.
s. c. Left thigh.
Figure 21. The same showing the right extremeties unfolded.
Parts named as in Plate V, Figure 3.
Figure 22. Embryo of *Adelonycteris fusca.*
I. Digit.
s. p. Left foot.
d. p. Right foot.
d. c. b. Right forearm.
a. s. Left ear.
t. Tail.
g. s. Left knee.
Figure 23. The same showing left extremeties partially unfolded.
Figure 24. Same showing right extremities unfolded.
Parts named as in Plate V, Figure 3.

Figure 25. ~~Five~~ Twin embryos of *Vesperugo carolinensis.*

Figure 26. Vesperugo carolinensis n. s. gravid, showing the position of uterus containing twin embryos.

Figure 27. Embryo of *Vespertilio albescens.*

Second specimen.

I, II, III, IV, V.	Digits. Mesopatagium lying in front of manus.
u.	Umbilical cord.
c. b. d.	Right forearm.
c. s.	Left wrist.
a. s.	Left auricle.

Figure 28. Embryo of *Vespertilio albescens.*

Third specimen.

I, II, III, IV, V.	Digits.
a. d.	Right auricle.
p. d.	Right foot.
u.	Umbilical cord.
t.	Tail.
g. s.	Left knee.

Figure 29. Embryo of *Vespertilio albescens.*

First specimen.

g. d.	Right knee.
u.	Umbilical cord.
p s.	Left foot.
g. s.	Left knee.
c. b. s.	Left forearm.
c. s.	Left wrist.
a. s.	Left auricle.

EXPLANATION OF PLATE VIII.

Figure 30. Profile view of embryo of *Vespertilio albescens*, showing the head not bound in flexion by the wings to the trunk, but moving up at right angles to the trunk when the pressure of the fœtal membranes is removed.

ilv.	Infralabial warts.
s.	Setæ on post-mental wart.

Figure 31. Head of same seen from beneath to display position of warts.

Figure 32. The right extremities of *Vespertilio albescens* unfolded.

UOFM

Figure 33. Embryo of *Rhynchonycteris naso*.

I, II, III, IV. Digits.

u. Umbilical cord.

t. Tail.

g. s. Left knee.

n. Proboscis.

a. s. Left auricle.

Figure 34. The right extremities of same unfolded.

Figure 35. The right manus of (dugong, *Halicore senegalensis*) the fifth digit abducted.

II, III, IV, V. Digits.

Fig. 1.

Fig. 4.

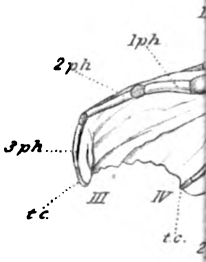


Fig. 9

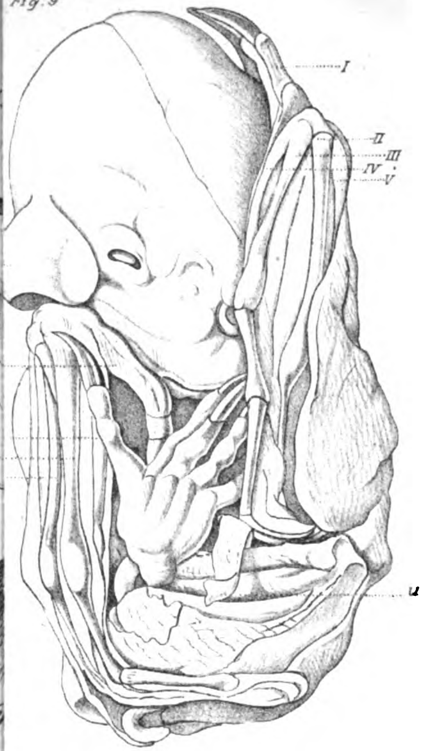
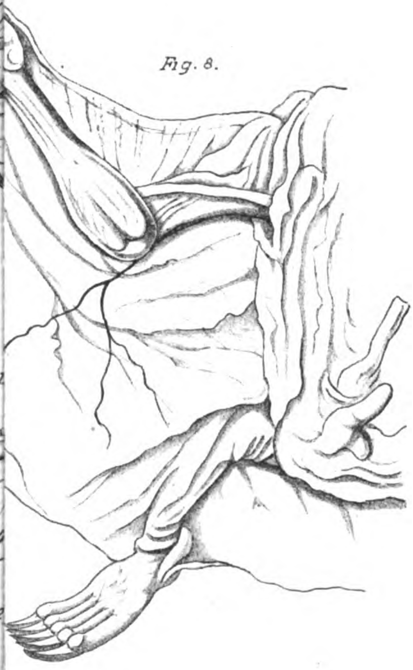
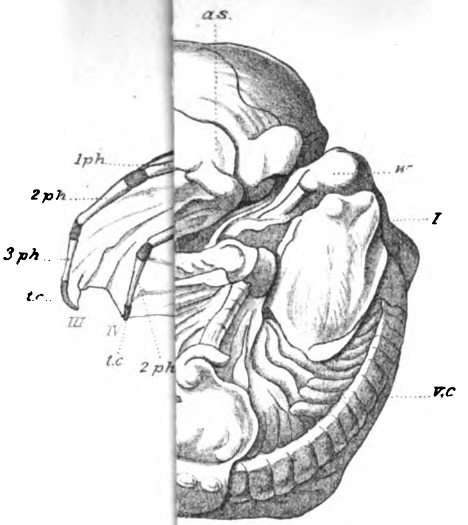


Fig. 8.

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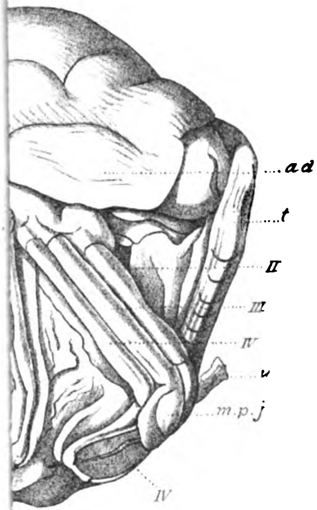
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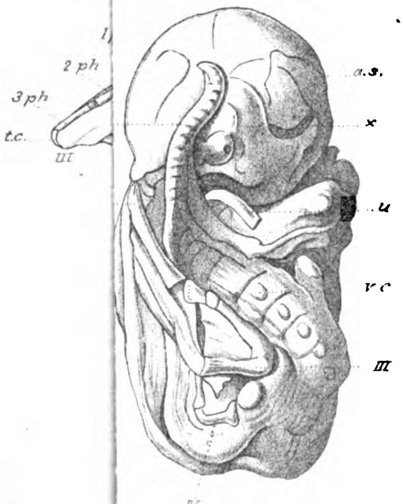
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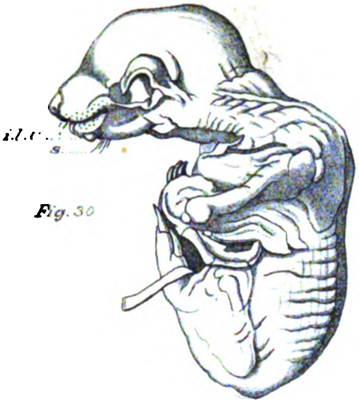

Fig. 30

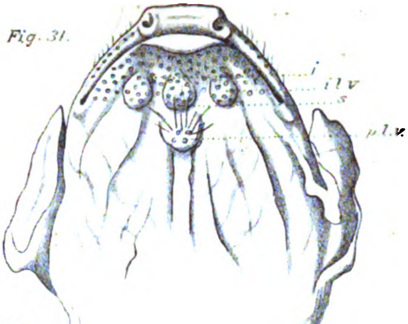

Fig. 31

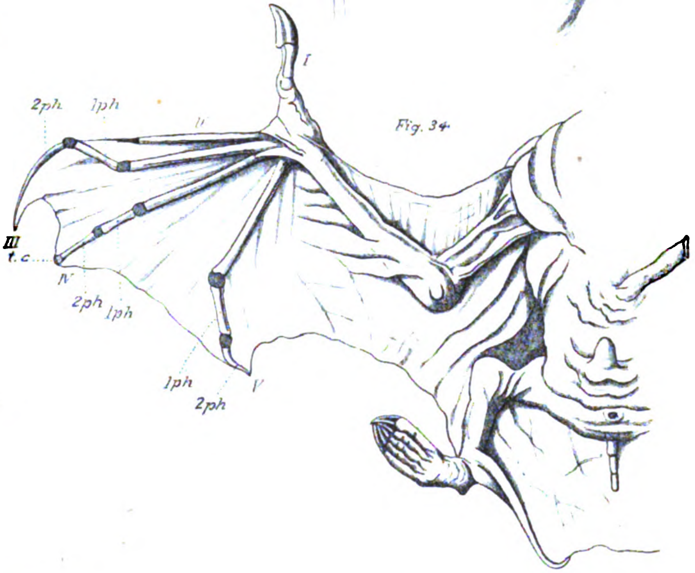

Fig. 34

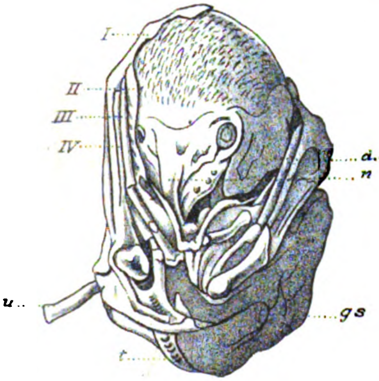

Fig. 33.

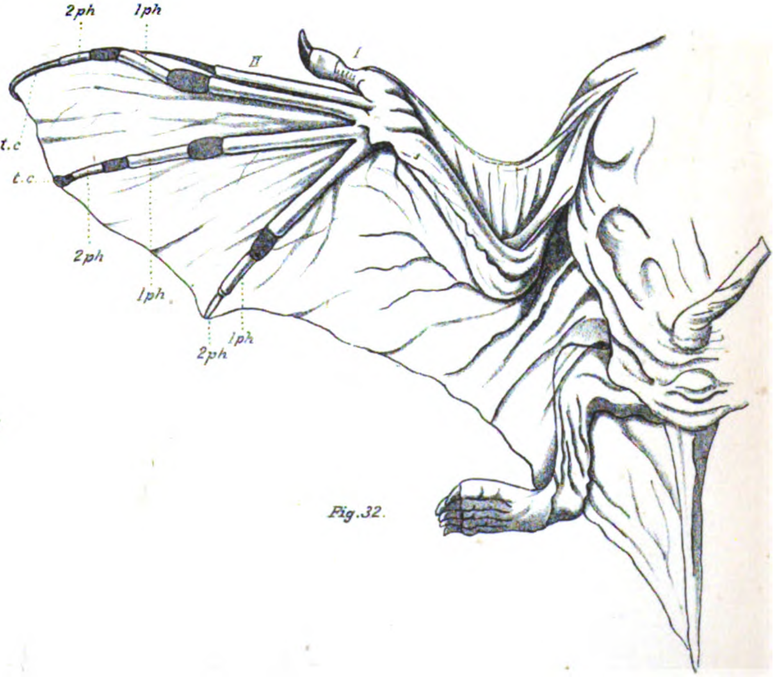

Fig. 32.

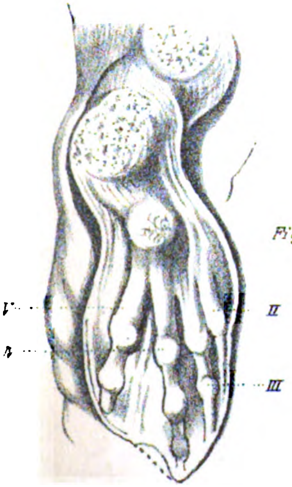

Fig. 35

Harrison Allen on Embryos of Bats.

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